

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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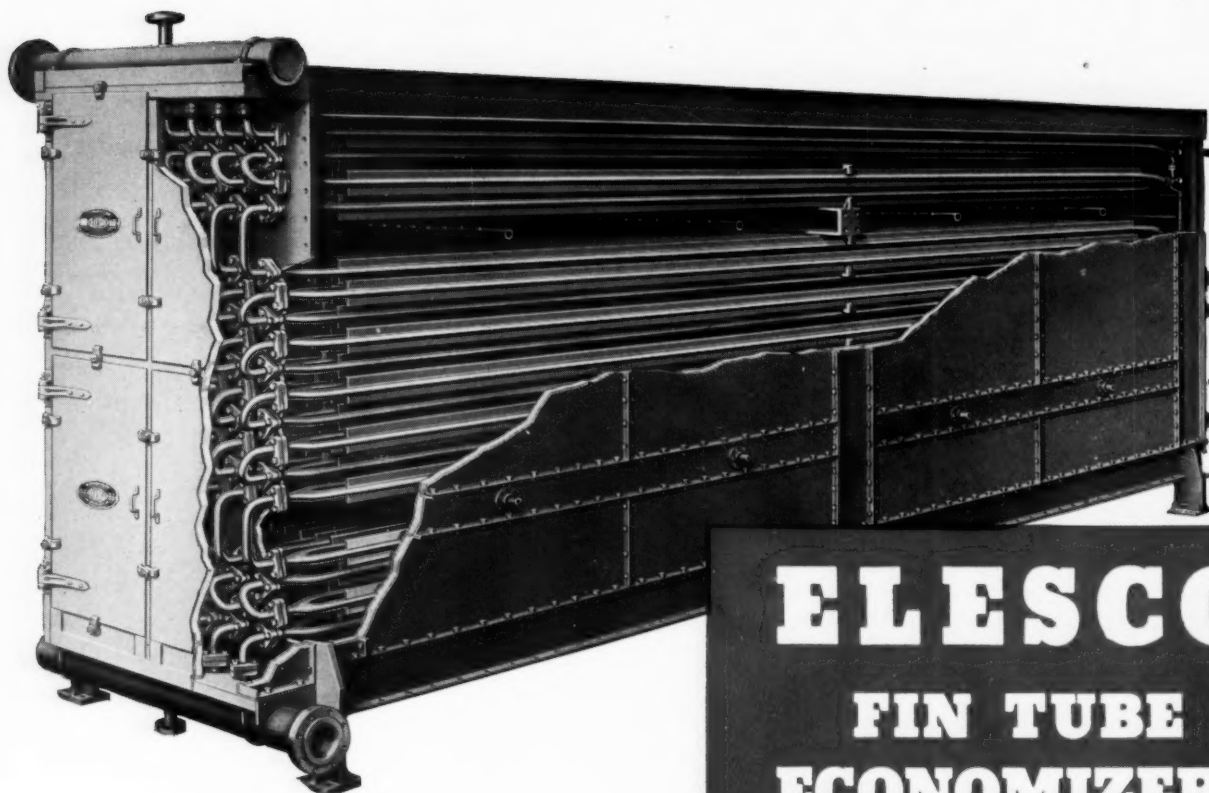
Looking up through slag screen into large pulverized coal furnace

Complex Silicate Scales in High-Pressure Boilers— Their Occurrence and Correction

Notes on Lubrication under High-Temperature Conditions

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VOLUME ELEVEN

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FOR AUGUST 1939

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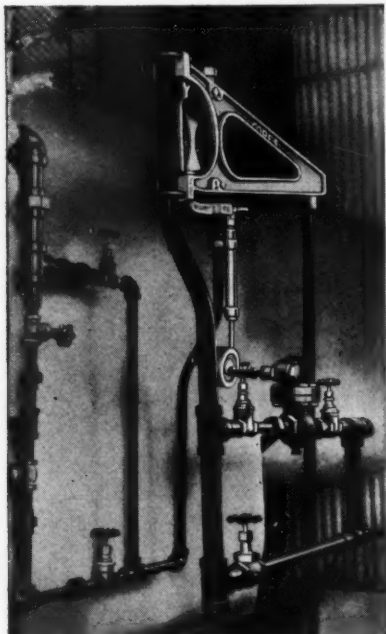
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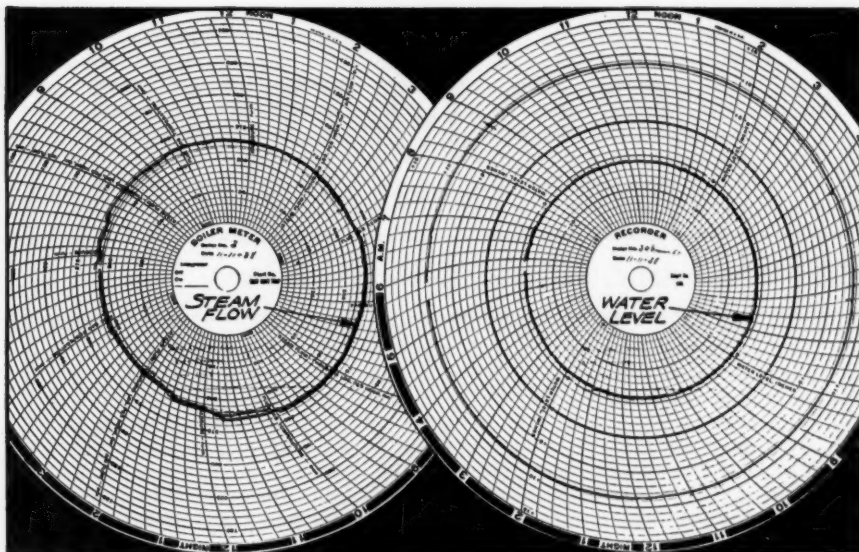
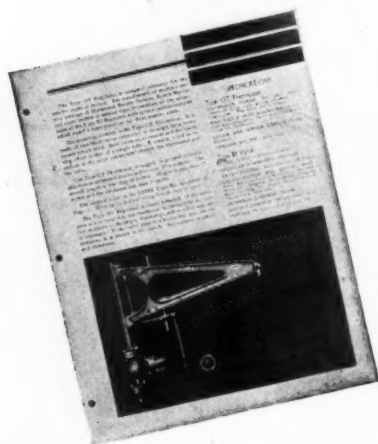
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EDITORIAL

Marine Practice Advances

Marine power plant practice has advanced more slowly than stationary practice because of conservatism born of certain limiting conditions afloat that do not apply on land, where considerations of space and weight do not obtain and where possible outage is a lesser factor because of interconnections with other plants or systems. However, present indications are that marine engineers are now ready to take advantage of the experience gained through progress in stationary practice to the extent of adopting higher pressures and temperatures, automatic combustion control, and making more extensive use of heat recovery equipment with a view to attaining greater economy in operation, also units of greater capacity per cubic foot of space occupied. This means, not only lower operating costs, but also saving in the amount of fuel carried which, in turn, permits greater cargo carrying capacity.

An impetus to these advances, in so far as American practice is concerned, is provided by the extensive ship-building program upon which the U. S. Maritime Commission has embarked. This program covers some five hundred ships to be constructed over a ten-year period, a substantial number of which are now building or have lately been placed in service. They include mostly cargo carriers, cargo-passenger vessels and tankers, having a speed somewhat greater than that generally employed heretofore. While some of the vessels will be diesel-driven, the greater number will employ steam with prevailing conditions of 450 lb pressure and 700 to 750 F total steam temperature, heat recovery in the form of economizers or air preheaters, and automatic combustion control in many cases. Under such steam conditions and with the embodiment of latest design features and improved cycles, adopted from stationary practice, it is believed that the steam-driven vessels will show a fuel economy comparable with those that are diesel-driven.

Incidentally, very excellent performance is reported for two privately-built American tankers that have been in operation for about a year with 600 lb pressure and 825 F total steam temperature.

The Maritime Commission has shown a disposition to pioneer further in an effort to attain still greater economy by planning one ship to employ steam at 1200 lb pressure and 950 F. While such steam conditions are no longer a novelty on land, they represent a big step for marine practice, and the results should go far toward settling certain long-standing controversial questions, among which is the necessity for close feedwater control. It is anticipated that many problems considered pertinent only to marine installations will be found solvable in the

light of stationary experience. Two or three foreign vessels have been partially equipped with very high pressure boilers of special design but the vessels were not initially designed for such steam conditions.

Obviously, all the ships included in the Maritime Commission's program will employ oil as fuel, pulverized coal not having been considered. The experiments conducted some years ago by the Shipping Board on the *S.S. Mercer* and one other vessel, were made when pulverized coal burning and fly-ash recovery were in their infancy. Since then much has been learned about these subjects from both the design and the operating standpoints. Should the matter again come up for serious consideration at some future time, as it probably will, it is likely that successful marine installations of pulverized coal will not be difficult. For the present, however, the problem is largely one of economics and as such holds greater concern for British than for American shipping interests.

A Challenge to Business

Notwithstanding the fact that the Seventy-sixth Congress, in its session just closed, was responsible for record peace-time appropriations and neglected to pass much-needed amendments to certain laws which in their present form appear to have impeded recovery, its curtailment of WPA activities and its bi-partisan last-minute refusal to commit the Government to an additional spending program, offers a challenge which business cannot afford to neglect.

While no relief in taxation is in sight, the action of Congress may be regarded as conducive to the re-establishment of confidence and an invitation to private industry to carry through in the restoration of prosperity and a consequent reduction in unemployment. If business fails to accept this challenge it will play into the hands of the advocates of continued governmental spending with its eventual dangers, who believe that the action of Congress will result in further recession and the necessity for still greater appropriations when it assembles again in January. Although the time is short for business to make its answer effective, it must exert every effort to this end; or else, become resigned to conditions of which it has long complained.

If business can demonstrate its ability to bring about a substantial degree of recovery within the next few months, with a corresponding degree of re-employment without undue governmental spending, it will not only have contributed to the restoration of confidence but it will be in a stronger position to demand that certain legislation, now accepted in principle, but hastily conceived, be constructively amended and equitably administered.

The challenge is there. Will business accept it?

Complex Silicate Scales in High-Pressure Boilers— Their Occurrence and Correction

Silica is objectionable in boiler water because it may lead to the formation of hard, dense scales having unusual resistance to heat transfer, and because turbine deposits containing silica are difficult to remove. Calcium and magnesium silicates can be prevented by the usual methods for controlling other calcium and magnesium scales, but in modern boilers the high temperatures and rates of heat transfer may promote the formation of a variety of complex silicates of soluble boiler water constituents, such as sodium and aluminum. Advanced analytical methods, such as X-ray crystallography, have identified these substances and advanced an understanding of the mechanism of their formation and means for preventing them. The most effective remedy is the removal of as much silica from the feedwater as possible. Research has also pointed to methods for accomplishing this, and practical application has been made by using coagulants having high adsorptive properties for silica. Two recently designed plants are described, as well as reaction tanks of modern design that have been found effective for this purpose.

In recent years attention has been focused on the detrimental effect of silica in water fed to high-pressure boilers because of the operating problems introduced by the occurrence of complex silicate scales on the heating surfaces and the formation of silicate deposits on the blading of steam turbines. Such difficulties have been limited largely to high-pressure boilers, but the marked trend to the installation of boilers of this type has made the problem of increasing importance. Corrective measures have not been readily effected because of the complexity of the siliceous compounds present in water supplies and because of the dearth of accurate knowledge relating to the exact composition of these compounds and their reactions under high-pressure and temperature.

Considerable research has been undertaken in recent years in this country and abroad on the chemistry of silicates in solution and colloidal dispersion in water and, following the assembly of these data, ways and means of correction and control of silicate scale have been devised.

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Notwithstanding this fact the elimination of siliceous deposits both from boilers and turbines is still a problem of great importance in many steam generating stations throughout the country. The deposition of simple or complex silicate scale on heating surfaces is closely related to the design of the boiler and is influenced not only by the amount and physical condition of the silica present, but also by the other salts which are present in the feedwater or in the concentrated boiler water salines.

General Aspects of the Silica Problem

For many years it has been recognized that silicate scales were particularly objectionable because of their high resistance to heat transfer. In boilers operating under relatively low pressure the silicate scale consisted largely of calcium and magnesium silicates. Where the formation of such deposits was encountered, their elimination was relatively simple, and softening of the water either by chemical processes or by zeolite minerals, or by the use of evaporators, effected control of such incrustations by removing the calcium and magnesium which had combined with the silica present in the supply. The solution of the present problem of control of silicate scales in high-pressure boilers is not so readily obtained. It has been demonstrated in the operation of many recently installed high-pressure boilers that silicate scale may be easily formed under certain conditions, even though calcium and magnesium are not present in any appreciable amount in the supply.

The most troublesome scales that have been experienced are the complex sodium-aluminum silicates or other compounds having similar chemical characteristics and physical structures. Such compounds may be formed on tube surfaces when the feedwater contains only a relatively small amount of silica and the combining elements entering into the composition of these scales. The exact mechanism of the formation of such deposits is not clearly understood, but there is reasonable evidence to indicate that they are laid down on the heating surfaces when the ratio of steam to the water passing through the tubes reaches a critical point. The formation of these deposits is further greatly influenced

by the high rate of heat input on the tube surfaces, by circulation and many other factors correlated with boiler design. With adequately conditioned water and with due care in the design of the equipment, high-pressure boilers can be operated satisfactorily, notwithstanding the high ratings, pressures and temperatures imposed. It is imperative, however, that the feedwater be of the best possible quality with respect to the elimination of scale-forming solids, and of the silica or other compounds which may tend to combine and form deposits on the heating surfaces. In recent years purification has become even more important because of the trend toward high makeup, necessitating chemical treatment of the feedwater. These requirements impose much more severe operating conditions than are encountered where the feedwater makeup is low or where all the makeup is secured from evaporators.

Measures for the Control of Silica Deposits

It is obvious that satisfactory operation of high-pressure boilers requires adequate conditioning of the water outside the boiler. However, even after such feedwater treatment has been made available, secondary internal treatment must be provided. Where silicates are absent or where there is no marked tendency toward the formation of this type of scale, phosphates and other chemicals used for secondary treatment may be sufficient to insure satisfactory performance of the boilers. Internal treatment has not, in all cases, been able to control the formation of silicate scales, although certain chemicals which have been used for this purpose have sometimes proved relatively satisfactory. In other cases complete elimination of the silica scales has not been effected by any type of secondary treatment. The only means of definitely assuring the elimination or control of these troublesome deposits is the reduction of the silica content of the water to the lowest possible concentration outside the boiler. A number of investigations have been made of silica removal by chemical means external to the boiler, and numerous patents have been issued to various investigators for processes designed to remove silica or siliceous compounds. Some of these processes have been put into practical operation and several large-scale plants are now in operation for this purpose. An investigation of this kind has been made during the past year at New York University, and this study has materially contributed to our knowledge of the chemistry of siliceous compounds in natural waters. An interpretation of these data, supplemented by the work of other research investigators, has indicated ways and means for the practical solution of the problem of the elimination of siliceous deposits from steam boilers.

Nature of Silica in Water

Increased recognition of the rôles played by silica and silicates in boiler scale formation necessitates a knowledge of the occurrence and nature of silica in natural waters. While silicon is never found as the free element, it combines with oxygen to form silicon dioxide which exists in various forms either in the free state or united with water or metallic oxides to form numerous complex silicates. Silicon dioxide and its compounds constitute roughly 80 per cent of the earth's crust. All natural waters contain silica in some form, largely as a result of the weathering of rocks. At ordinary temperatures a

weakly acidic water, such as one containing carbon dioxide, readily reacts with silicates whether dissolved or suspended in water and with the complex silicates in rock formations. Silicic acid is released into the water and the ions of the alkaline metals making up the silicates pass into water as soluble carbonates. This process may be represented by the following equilibrium reaction:



The equilibrium is greatly affected by temperature changes. At the period of volcanic rock formation the high temperatures resulted in shifting the equilibrium to the left, forming metallic silicates and releasing carbon dioxide. At low temperatures the products, silicic acid and carbonates, are more stable, and the reaction proceeds to the right as water containing carbon dioxide passes over silicate formations.

The silica content of natural waters varies in different localities, but it tends to be higher in softer waters; thus waters in the Pacific Northwest and certain coastal areas frequently have a greater silica concentration than the harder waters of other localities. The weathering process may be affected by the presence of organism such as the diatom which requires silica as an essential of its structure.

Silicon dioxide occurs in nature in six distinct mineral forms (1): quartz, chalcedony, opal, tridymite, cristobalite and lechatelierite. These forms vary in the method of their formation, crystalline structure and in several other physical properties. Silicon may occur as a silicate in combination with many metals including sodium, iron, aluminum, calcium, magnesium and others. The solubility of the majority of these silicates in water is relatively low.

In order to evaluate properly the methods of removing silica from water to be used for industrial purposes, or methods of preventing the deposition of silica as boiler scale, the condition in which silica exists in natural waters should be known. That is, does silica exist as a crystalloid or as a colloid? Stumper (2) investigated this problem by a number of different tests.

A comparison of the silica concentration indicated by gravimetric (colloidal plus crystalloidal) test and a colorimetric (crystalloidal only) test showed that up to a SiO_2 concentration of 5 parts per million all of the silica present was in the crystalloidal state, that is, molecularly dispersed. Beyond a concentration of 5 ppm SiO_2 the gravimetric test gave higher results, indicating an increasing amount of colloidal silica. That these results were not wholly due to the insufficiency of the colorimetric test above 5 ppm was indicated by the work of Harman (3). Working with sodium silicate solutions having ratios $\text{Na}_2\text{O}/\text{SiO}_2$ of 1:1 and 1:4, he concluded that "In extremely dilute solutions of these ratios practically all the silica exists in a crystalloidal state, but with increasing concentration increasing amounts of colloidal silica are manifested." Stumper also subjected a variety of waters to filtration through "white of egg" membrane filters. As a result of this investigation he concluded that only from 2.5 to 20 per cent of the total silica in natural waters is colloidally dispersed.

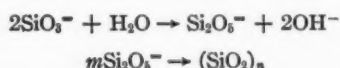
As a result of an investigation of a number of potable water supplies in England, Thresh and Beale (4) concluded that in 99 per cent of the cases the silica was molecularly dispersed. Dienert (5) believes that the ex-

istence of crystalloidal silica in natural waters is due to the action of dissolved electrolytes in converting colloidal silica into non-colloidal silica.

Thus the nature of silica in water depends to a great extent upon the accompanying ionic substances, particularly upon the hydrogen-ion concentration. While the chemistry of silicic acid in aqueous solution is rather a controversial subject, a reasonable explanation has been proposed by Jander (6) who states that the silica in water exists according to the following equilibrium:



Thus, only anions of a mono- or di-silicic acid exist in an equilibrium with one another which depends on the pH of the solution. According to the above scheme, with an increased pH the reaction is shifted to the left, with a preponderance of mono-silicic acid. Jander states that (a) mono-silicic acid (H_2SiO_3) is stable at a pH above that of a normal caustic solution, (b) di-silicic acid ($\text{H}_2\text{Si}_2\text{O}_6$) is stable from pH 10.0 to 13.5 and (c) below pH 10.9 the silicic acid becomes more or less aggregated, and with an increase in hydrogen-ion concentration tends to the nature of colloidal polysilicic acids. This may be expressed as follows:



It would appear, then, that for natural waters there exist simple forms of molecules stable in the acid region, and di-silicic acid, a portion of which is colloidal dispersed. In alkaline waters there exists an equilibrium between mono- and di-silicic acid, the position of the equilibrium depending largely on the hydrogen-ion concentration. It must also be recognized that inorganic salts, such as sodium, magnesium and calcium, will affect the equilibrium; further, depending on the hydrogen-ion concentration, silica will precipitate as the mono- or di-silicate of calcium and magnesium, or as complex silicates of other metals.

Having formulated a picture of the nature of silica and silicates in water, we may derive, theoretically, methods by which silica may be removed from boiler feedwater:

1. The condensation of the molecularly dispersed mono- and di-silicic acids to the colloidal poly-silicic acids, according to the scheme outlined above, by adjustment of the hydrogen ion concentration, ionic strength, temperature, etc., with the removal of the aggregated poly-silicic acids by colloidal means, filtration, salting out, precipitation, etc.

2. The precipitation of the mono- and di-silicic acids as insoluble silicates and their removal by sedimentation or filtration. Such a process would necessitate an excess of precipitating chemical and would be limited by the solubility of the resulting silicate; or use may be made of a substance which in water would be highly adsorptive toward silica and the removal would thus occur by adsorption rather than by compound formation.

Results of Research on Silica Removal

Treatment for the prevention of silicate scale in boilers operating at relatively low pressures may be either internal or external, depending primarily on local conditions.

Internal treatment has been recommended in certain cases and has been found to limit certain types of silicate deposits. Among the products which have been used

with some success for internal treatment are, iron compounds, the sodium phosphates and miscellaneous organic materials such as starch, tannins and tannic acid and the glucosides. The action of these compounds has been either to maintain the silica in solution or to precipitate it as a non-adherent scale. The effect depends upon the operating conditions encountered, especially the boiler pressure, heat input on the tube surfaces and



Fig. 1—Photomicrograph of boiler scale showing trapezoidal faces typical of analcite crystals

the condition in which silica and other constituents are present in the boiler water salines.

As a general statement it may be said that, where the problem of silicate scale formation is encountered in high-pressure boiler installations, it is essential to inaugurate external treatment to reduce the silica content to the lowest concentration and, further, to determine the maximum concentration of silica in the boiler water, at which point the deposition of complex silicates is not likely to occur. Supplementary internal chemical treatment in addition to external treatment may also be necessary.

A number of investigations have been made of the external treatment of the boiler feedwater by chemical coagulation for the removal of silica.

Stumper (2) investigated the effect of a number of chemicals in removing silica from a natural water containing 13.5 parts per million SiO_2 . He found that the aluminates of sodium, barium and calcium were the most effective reagents. At ordinary temperatures residual silica concentrations as low as 0.5 ppm were obtained with approximately 200 ppm of sodium aluminate. At a reaction temperature of 100 C the efficiency of a given dose of aluminate was somewhat decreased. Increasing the dose of sodium aluminate above approximately 250 ppm

resulted in an increased residual silica concentration presumably due to the formation of soluble sodium silicate. Since he found that silica removal with the aluminates was an exponential function of the amount of coagulant added, Stumper concluded that the mechanism of silica removal was largely one of adsorption.

Lindsay and Ryznar (7) also investigated the removal of silica with sodium aluminate. In addition to con-

ferior to those obtained by the use of ferric sulphate and a base *in situ*. From a graphic analysis of his data, Schwartz concluded that the mechanism of silica removal was one of adsorption rather than of compound formation.

A number of investigations have been recently completed in the Sanitary Engineering Laboratory of New York University. A natural water containing, at the time of experimentation, from 2 to 3 ppm of soluble SiO_2 was coagulated with varying amounts of a ferric sulphate-sulphuric acid solution prepared by the reaction of sulphur dioxide with a ferrous sulphate solution. When coagulation was carried out in the acid pH range no silica removal was observed. Coagulation at an alkaline pH of 8.0 to 9.0 with the ferric sulphate solution and lime reduced the silica concentration to 1.5 ppm.

Somewhat better results were obtained when samples were treated as follows: flocculation with ferric sulphate and acid at a pH of 3.5 to 4.5 with the release of colloidal ferric oxide followed by alkalization to a pH greater than 7.5. Such a treatment, with concentrations of ferric sulphate of about 50 ppm Fe, resulted in a residual silica content of 0.5 ppm. Presumably, the hydrogen ion concentration at which the preliminary treatment took place was such as to affect the nature of the dissolved silica and to render it more amenable to adsorption on the surfaces of the colloidal ferric oxide and to subsequent coagulation. This is indicated by the fact that other samples, similarly treated, but with lower quantities of iron and acid and resultant pH values of 5.5 to 6.0, did not evidence an equally good silica removal.

Straub (10) has reported on the value of magnesium oxide in removing silica from solution at high temperatures by the formation of a magnesium silicate. Silica added as sodium silicate and caused to react with caustic and excess magnesium oxide in bombs at temperatures of 182 to 282 C was reduced from about 240 to 6 ppm after the treated solutions were passed through a filter. Addition of alumina to the above mixture resulted in a further decrease in soluble silica to less than 3 ppm.

Christman (11) reports that magnesium sulphate and sodium aluminate will effectively remove silica due to the formation of flocculent magnesium-aluminum silicate. Sufficient aluminate must be added to give a residual soluble alumina.

The results of the experimentation thus reviewed indicate that with proper control silica may be removed from boiler feedwater by ordinary chemical coagulation if the coagulant chosen possesses high adsorptive properties. The experimental data indicate that an alkaline pH of coagulation will be required. The amount of silica which will be removed will be largely a function of the initial concentration, the amount of coagulant added and the time and temperature of reaction. While silica removal will be most efficient at low temperatures, it may be removed in hot process systems with a slight increase in coagulant dose. Coagulant doses in the neighborhood of from 50 to 100 ppm may be expected to reduce the silica content of most natural waters to a point where it will cause minimum difficulty in boilers and turbines.

Nature of Scales Containing Silica

Although it has long been known that silicate scales are objectionable, it is only within recent years that the exact structure and identification of such deposits have been clearly established. The earlier procedure for de-



Fig. 2—Photomicrograph of section cut parallel to surface of deposition

firming the general results of Stumper as to the efficacy of sodium aluminate treatment, they established an optimum pH of approximately 8.5 and found that recirculation of precipitated sludge increased the silica removal. These investigators also concluded that the silica removal was largely an adsorptive process.

The use of ferric compounds has been suggested for the removal of silica from water and this type of treatment is now being employed at a number of plants. Liebknecht (8) proposed passing the silica-bearing water through a bed of dried ferric or alumina oxide gels with revivification of the bed, when necessary, with a weak alkaline solution.

Recently, Schwartz (9) reported a number of investigations on the removal of silica with ferric sulphate and hydrous ferric oxide. He found that excellent silica removal could be obtained when the water was treated with ferric sulphate and lime to a pH of about 9.0. With ferric sulphate doses of approximately 75 ppm, residual silica concentrations as low as 2 ppm were obtained when the pH was properly adjusted. Investigations of coagulation at an acid pH indicate that little or no silica removal was obtainable under such conditions. It was also found that hydrous ferric oxide gave results in-

termining the composition of such incrustations consisted of making a chemical analysis of the deposits and combining the elements identified. The analyst then recorded this hypothetical combination and generally reported the scale as silicates of calcium or magnesium.

Experiences in attempting to control the formation of silicate deposits have required a much more intensive study and the identification of the offending scale by a more exact science. These studies have revealed many interesting forms of crystalline deposits which formerly defied accurate identification by chemical analysis. It is now recognized that many of the troublesome silicate scales which have formed on tubes of high-pressure boilers and which have accumulated on the blades of steam turbines are closely related to compounds formed under geological conditions, and it is surprising that the scales which have been formed artificially in steam boilers have such a close similarity to compounds occurring in the earth's crusts. This similarity is particularly noticeable in comparing boiler scales with deposits in the vicinity of volcanoes, where compounds have been formed by fusion resulting from high temperatures and high pressures. The resemblance in structure is especially apparent between the analcite scales which have been identified in boilers and the analcite identified in certain volcanic formations. As an illustration of this fact Table 1 presents chemical analyses of two scales of this type compared with an analysis of pure analcite.

Up to the present time only a few types of boiler scales have been definitely identified and classified as minerals by their geological terminology. It is probable that continued research and investigation along these lines will reveal many complex compounds, identification of which has not been made or whose mineralogical structures have not been properly reported. This statement probably holds true not only for the silicate scales found in boilers but for many other types of deposits which

TABLE 1—CHEMICAL ANALYSES OF BOILER SCALE SAMPLES COMPARED WITH PURE ANALCITE

		Boiler Tube Scale A	Boiler Tube Scale B	Pure Analcite
Water	H ₂ O	9.10	7.68	8.10
Silicon dioxide	SiO ₂	50.28	47.84	54.60
Ferric oxide	Fe ₂ O ₃	1.74	2.00	...
Aluminum oxide	Al ₂ O ₃	20.98	22.20	23.15
Calcium oxide	CaO	2.72	4.50	...
Magnesium oxide	MgO	Trace	Trace	...
Sodium oxide	Na ₂ O	12.40	13.40	14.07
Sulphuric anhydride	SO ₃	0.27	1.92	...
Phosphorus pentoxide	P ₂ O ₅	0.06	0.41	...
		99.55	99.95	100.00

have been erroneously identified by the less informative chemical procedure in making the analyses. Among the silicate scales which have been positively classified in studies made by one of the authors¹ are analcite, noselite and natrolite. These scales are all double silicates of sodium and aluminum, as is indicated by the chemical formulas given below, and were identified by X-ray and petrographic analysis. Doelter (12) states that analcite, Na₂O·Al₂O₃·4SiO₂·2H₂O, will form whenever the components exist in a closed system between 350 and 800 F. Above the upper limits, namely 800 F analcite will pass into the anhydrous compound nepheline, which has the formula Na₂O·Al₂O₃·2SiO₂. Below a temperature of 350 F natrolite may form. The latter has the chemical formula 2H₂O·Na₂O·Al₂O₃·3SiO₂. A compound somewhat similar in nature which has been recently identified

is noselite, Na₈Al₆Si₆O₂₄·SO₄. Likewise hauynite, 3-(Na₂,Ca)O·3Al₂O₃·6SiO₂·2(Na₂,Ca)SO₄, has been identified as a possible combination in complex silicate scales.

Recent studies in this field have revealed many interesting crystalline formations which at earlier times defied accurate identification by less scientific means. As

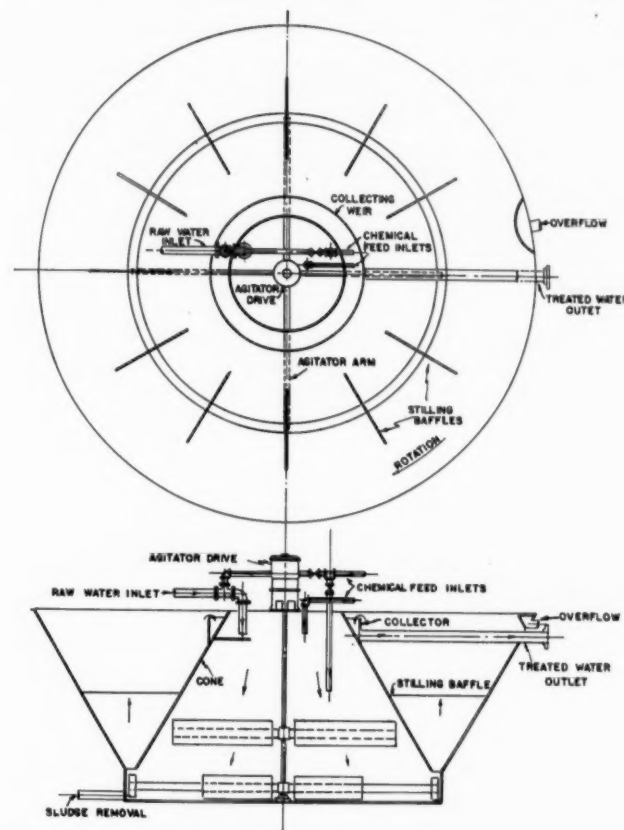


Fig. 3—Spaulding tank for softening with lime and employing precipitated sludge

previously observed, the composition of these deposits may be determined either by petrographic or X-ray diffraction methods. In Fig. 1 is reproduced a photomicrograph of a boiler scale showing the dominant trapezohedral faces typical of the crystallization of analcite under conditions of maximum concentration and alkalinity. Fig. 2 is a photomicrograph of a thin section of the same boiler scale cut parallel to the surface of deposition, showing the orientation of the submicroscopic impurities at the intersection of crystallographic planes.

The application of X-ray and petrographic analyses to a study of boiler scales promises to greatly enhance our present knowledge of the nature of such deposits, and points the way to a better understanding of their formation and ultimate control. It is obvious that the X-ray method does not come within the scope of practical power plant control, since to carry out such work effectively requires expert observers and costly and complex equipment. It does, however, offer an intriguing study for research investigators and it is not unreasonable to assume that the cost of such studies may be justified where other types of analytical procedure fail to produce adequate data leading toward the solution of the problem. Some commercial laboratories have already recognized the application of these methods to the identification of boiler scales and it is expected that development along these lines may be forthcoming in the immediate future.

¹ S. T. Powell.

Typical Plant Installations

Since the removal of silica by chemical coagulation is largely a matter of adsorption, the efficiency of the silica removal process will depend primarily on so preparing the admixture of coagulant and silica-bearing water as to provide the maximum amount of intimate contact between the coagulant and the soluble silica. There are many types of coagulation basins which may be utilized for this purpose, and a choice of the equipment

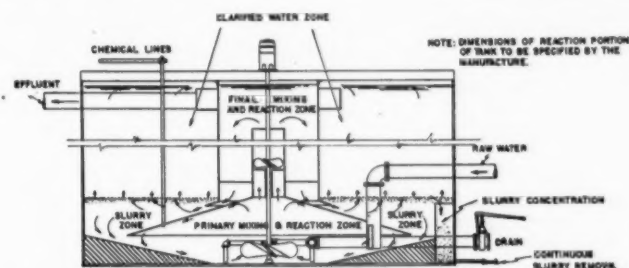


Fig. 4—Diagram of "Accelerator" tank utilizing principle of sludge recirculation

selected will be influenced by economic conditions. There has been a marked development along this line within the past few years and several types of equipment have been designed to bring about this desired effect. The most important are those embodying the principle of passing the water through a blanket of sludge. Such appliances are being successfully used not only for silica removal but for other purposes in water purification. The adoption of such units has grown rapidly and great number have already been installed. Descriptions of two of these designs are given in this discussion, as they may be of interest to engineers having water-treatment problems, in connection with which they may be used to advantage.

Fig. 3 shows the Spaulding² type of tank for softening with lime, in which process the repeated contact of the water with the precipitated sludge assures an effluent that is stable with respect to the solubility of calcium carbonate. In the operation of this tank the treated water enters the inverted cone at the center and is stirred with paddles to effect flocculation of the coagulated precipitate. The water, containing that part of the floc which has not settled out, passes upward through an annular opening into the outer part of the tank, which is formed by the central upright cone and outer inverted cone. Since the cross-section of this part of the tank increases as the elevation increases, the upward velocity of the water is proportionately reduced. At a certain elevation the velocity becomes just sufficient to support the floc, which forms a blanket beneath a layer of relatively clear water. The elevation of this sludge blanket is governed by the rate of flow through the plant and the withdrawal of excess sludge. The scrubbing of the water by the blanket of floc during its upward passage through the cone assures a completeness of

reaction and retention of suspended matter that is not ordinarily obtainable in standard subsidence basins.

A reaction and settling tank utilizing the principle of recirculation of sludge is demonstrated in the "Accelerator" tank.³ A schematic diagram, illustrating its operation for cold process lime-soda softening, is shown in Fig. 4. The chemicals are added directly to a relatively thick concentration of precipitated sludge near the bottom of the tank, and the raw water is treated with this mixture and is stirred at a higher velocity than is commonly employed in coagulating tanks. It is the purpose of this design to bring about the initial softening reaction in the presence of sludge so that precipitation takes the form of accretions to existing particles, rather than the formation of new particles of much smaller size. From the primary mixing and reaction zone, the water flows upward into a final mixing and reaction zone, carrying with it a high concentration of sludge that is kept suspended by relatively rapid mixing. Flowing downward out of this area, the water enters an outer section of much larger diameter which is free from turbulence and which permits the much slower upward flow of the water to a take-off weir. The sludge settles out and is returned to the bottom of the tank, or is skimmed off into a concentrator compartment and removed continuously.

Both the Spaulding conical apparatus and the accelerator are susceptible to modification to adapt them to treatments other than cold-process softening. Both of these types of tanks have been studied to determine their efficiency for the removal of silica from boiler feedwater, and the results obtained have shown them to be more effective than the standard design of tanks that were considered.

As has been indicated in this discussion, there are many chemical means by which silica may be removed from water. Iron compounds, particularly ferric and ferrous sulphate, ferric chloride and chlorinated copperas, are particularly effective and a number of recently designed plants utilize these compounds for the removal of silica. Iron compounds may be purchased in the form desired, or in some cases it may be preferable and economical to

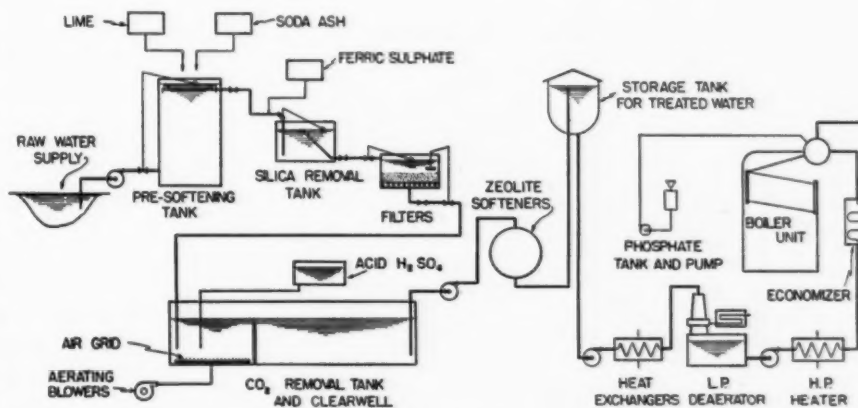


Fig. 5—Flow sheet of silica removal plant

prepare them at the point of use. Where ferric sulphate is to be used it may be purchased from chemical manufacturers who are now prepared to furnish a satisfactory product, or it may be prepared by the reaction of sulphurous acid and oxygen on iron filings or ferrous

² The Permutit Company.

³ International Filter Company.

sulphate. This process has been described by Wartman and Keyes (13). The sulphur dioxide may be purchased in compressed cylinders or made at the plant site by the combustion of crude sulphur in a sulphur burner. Although to our knowledge no plant for silica removal has been designed embodying this method of ferric sulphate preparation, the process will warrant consideration.

A flow sheet for one of the first large plants to include silica removal as a distinct step in the feedwater treatment is given in Fig. 5.⁴ The softening chemicals (lime and coagulant with soda ash being included only occasionally) are added to the water in two large prededimentation tanks, where they are flocculated by mechanical means. This accomplishes partial softening and a major reduction in suspended solids. The clarified water flows from these tanks to a second battery, where removal of silica is brought about by means of coagulation with ferric sulphate, no adjustment of the pH being required. These tanks are of the ordinary design of plain subsidence tanks operated on a fill-and-draw principle. The treated water is then filtered, adjusted with acid and aerated to remove carbon dioxide and then further softened by means of horizontal zeolite pressure softeners. By means of this treatment the silica content of the boiler feedwater is maintained at 2.5 to 3.0 ppm.

In Fig. 6 is given the flow sheet of a recently designed plant for the preparation of feedwater for a 900-lb boiler installation, embodying the use of practically 100 per cent makeup, which employs silica removal as an essential portion of the process.⁵ The feedwater at this plant is polluted by domestic and industrial wastes, including contaminated cooling water and oil. A system for complete treatment of the feedwater for high- and low-pressure boilers is being installed. Coagulation and

softening with lime, soda ash and ferric sulphate has been provided. After coagulation, the water is filtered through anthracite, followed by pH adjustment with acid, prior to filtration through carbonaceous zeolite, so arranged as to operate in either the sodium or hydrogen cycle. Supplementary deaeration with sodium sulphite is provided following the boiler feedwater heater.

Acknowledgments

The work described in this paper was made possible by a fellowship established by the Freeport Sulphur Company, and their assistance is hereby acknowledged. We greatly appreciate the helpful assistance and direction furnished by Mr. D. B. Mason, Technical Director of the Company.

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⁴ Stone & Webster Engineering Corporation, Consulting Engineers.

⁵ United Engineers & Constructors, Inc., Consulting Engineers.

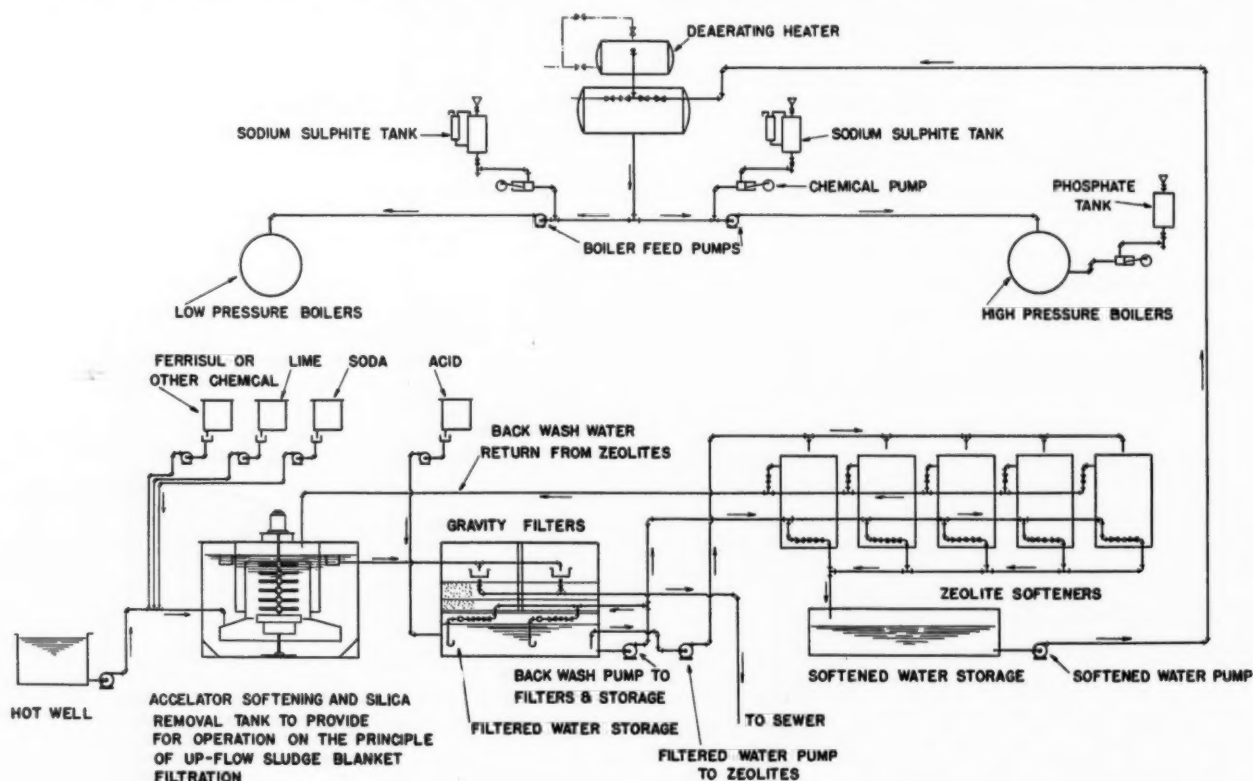


Fig. 6—Flow sheet for silica removal with 900 lb steam pressure and 100 per cent makeup

Drying Pulverized Coal

By B. J. CROSS

Combustion Engineering Company, Inc.

This describes a series of experiments made to determine the equilibrium moisture content of four different coals under varying atmospheric conditions, as to temperature and humidity. Drying and hydration curves were plotted from the results of the experiments for each coal and the different sets of conditions.

WE need look back only a few years to the time when a coal dryer was considered to be a very necessary part of a coal pulverizing system. These dryers were often large and cumbersome, and represented a considerable part of the investment charge of the installation. They also added to the power and fuel charges of operation. While the drying of coal prior to pulverizing and burning is just as important now as it was then, the separate coal dryer is practically obsolete and its function has been taken over by the pulverizer.

As practically all present-day coal pulverizers are of the air-swept type, the coal must be reasonably dry as it leaves the grinding chamber in order that it may be floated out of the mill by the air stream. The drying of coal is also important in securing efficient combustion.

In storage installations, when air is circulated through the mill system in a closed circuit, heated air or flue gas is added to the circuit ahead of the mill and vented from the system usually after the cyclone separator. In

direct-fired systems, heated air is supplied to the pulverizer from which the entire mixture of coal and air is vented into the furnace. As far as drying is concerned, a direct-fired mill can be treated as a mill of a storage system with 100 per cent venting.

The degree of drying accomplished in a mill is determined by the amount and temperature of the air or flue gas added to and vented from the system. Enough heat must be supplied to heat and evaporate a part of the coal moisture and to heat the coal and its residual moisture to the temperature of the mill discharge. It is also important that a sufficient volume of air or flue gas be added to carry the evaporated moisture out of the system.

All coals are to some degree hygroscopic. If a wet coal is exposed to air it will lose moisture until it reaches an equilibrium point after which it will gain and lose moisture according to changes in the humidity and temperature of the air. The amount of moisture held by coal when it is in equilibrium with air at a given condition will vary with the type of coal. Generally, the lower its rank, the higher will be its moisture content at its equilibrium point.

In a series of experiments, made to determine the equilibrium moisture content of coal with different atmospheres, four types of coal were exposed to air under controlled conditions of moisture and temperature. The apparatus used is shown in Fig. 1. Air was first passed through a saturator held at a definite temperature. After leaving the saturator the air was passed through a coil of tubing submerged in the constant

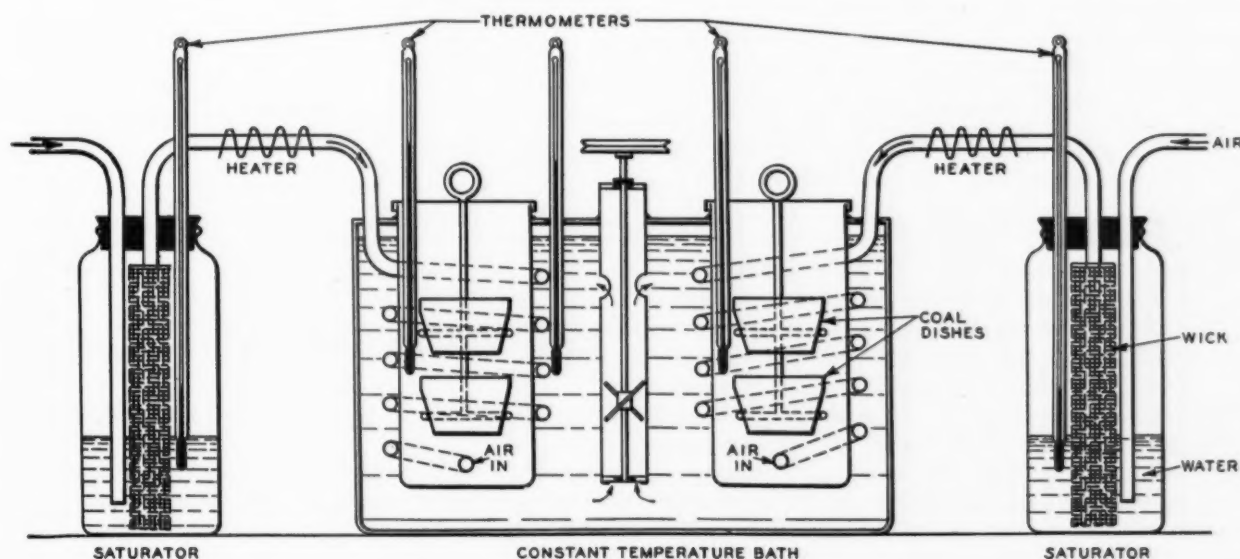


Fig. 1—Sketch of apparatus used in the experiments

temperature bath and then into the chamber containing the coal which was also submerged in the bath. The tube between the saturator and the constant temperature bath was kept at a higher temperature than the saturator to prevent condensation. The constant temperature bath was kept at a temperature above that of the saturator depending upon the degree of humidity decided upon.

One-gram samples of pulverized coal were put into weighing dishes and placed in the compartment in the

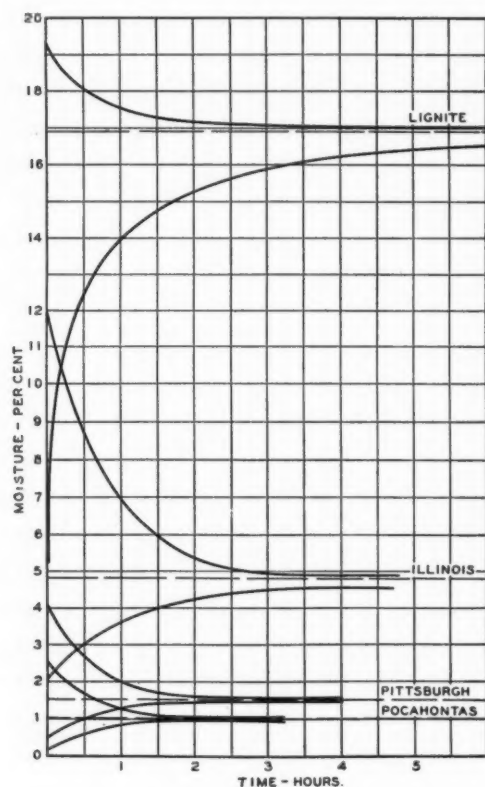


Fig. 2—Equilibrium curves for moisture with atmosphere 125 F, 85 per cent saturated

bath. These samples were weighed at one hour intervals to determine the change in moisture content. Low moisture coals required about three hours and high moisture coals five hours, to reach equilibrium.

The graphs shown in Fig. 2 are the experimentally determined equilibrium curves for four different coals with air at 125 F and 85 per cent humidity. One moist sample and one dry sample of each coal were exposed to the atmosphere so that a pair of curves could be obtained. The upper curve of this pair is the drying or dehydration curve and the lower the hydration curve. The hydration curves for lignite approached the equilibrium line at a much slower rate than the dehydration curves. Once these high moisture coals are thoroughly dried it is difficult to bring them back to their original moisture condition by exposing them to humid atmospheres. Possibly the moisture is held in a colloidal substance that is partly broken down by heat. It is the dehydration curves, however, that are of chief interest. The median line which these two curves approach represents the equilibrium moisture content of the coal with this particular atmosphere. At this equilibrium moisture content there is a balance between the vapor pressure of the moisture in the coal and the vapor pres-

sure of the moisture of the air, and there is in effect no interchange of moisture.

The moisture content of the coal at this equilibrium condition represents the limit of drying that can be obtained with a vent condition of 125 F and 85 per cent saturation. The vapor pressure of the moisture in the coal is the same as that of the air. If more drying is required, more heat must be supplied to increase the mill and vent temperature, and the quantity of air must be increased to lower the vapor pressure of the moisture in the vented air below that of the moisture in the coal.

The graph of Fig. 3 shows dehydration curves and equilibrium points for a Pittsburgh coal with four different atmospheres. The air temperature was held constant and the humidity was varied. It is evident that the moisture in the coal exerts a sub-normal vapor pressure and the lower the moisture content of the coal, the greater the lowering of its vapor pressure below normal. As more of the moisture is driven off, the more tenacious is the residual moisture held. The vapor pressure at a moisture content of 1.6 per cent is 85 per cent of that of water and, as the moisture content is successively reduced to 1.2, 1.0 and 0.8 per cent, the vapor pressure is 75, 65 and 55 per cent of normal water vapor pressure. Something more than evaporation is involved in the removal of this residual moisture. It is known that when dry coals are wetted, heat is given off and this amount of heat must be added, in addition to the latent heat of evaporation, in order to remove the moisture absorbed.

These curves do not represent the actual drying that may be accomplished in a pulverizer but rather the theoretical limits of drying. The laboratory experiments by which the curves were derived represented ideal conditions of drying which, principally because of limited time, cannot be reproduced in the pulverizer. The average time that coal remains in a pulverizer is about one minute. This limitation in the time element is

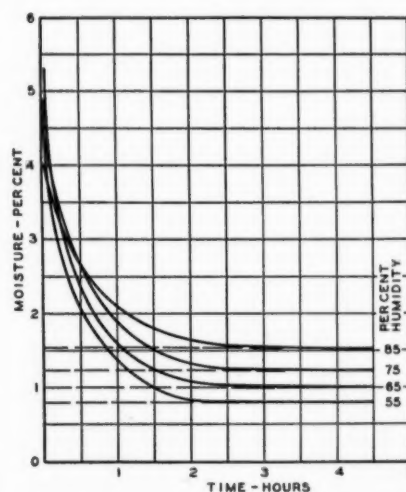


Fig. 3—Dehydration curves for Pittsburgh coal with air at 125 F and different humidities; vent temperature 125 F

partly compensated by the thorough agitation and ventilation of the coal in the mill.

The quantity of heat required to reduce the moisture content of coal a given amount may be calculated, whereas the quantity of air necessary to produce the required vent conditions is best determined from trial calculations. If, for example, it is desired to reduce the

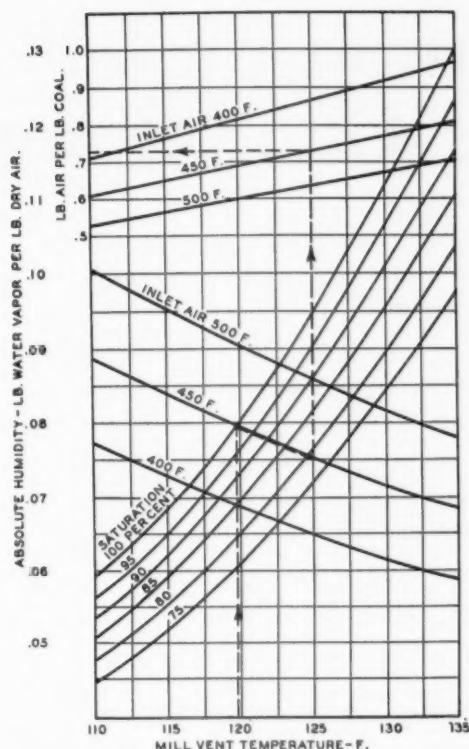


Fig. 4—Curves for Pittsburgh coal; reduction in moisture 6 to 1½ per cent

moisture content of a Pittsburgh coal from 6 per cent to 1½ per cent, the curves shown in Fig. 4 show the amount of air required at different initial and vent temperatures. The mill rating is 12 tons per hour and the power requirement is 12.5 kw per ton and eighty per cent of the electric energy is assumed to be converted into heat.

It may be seen that at an inlet temperature of 450 F,

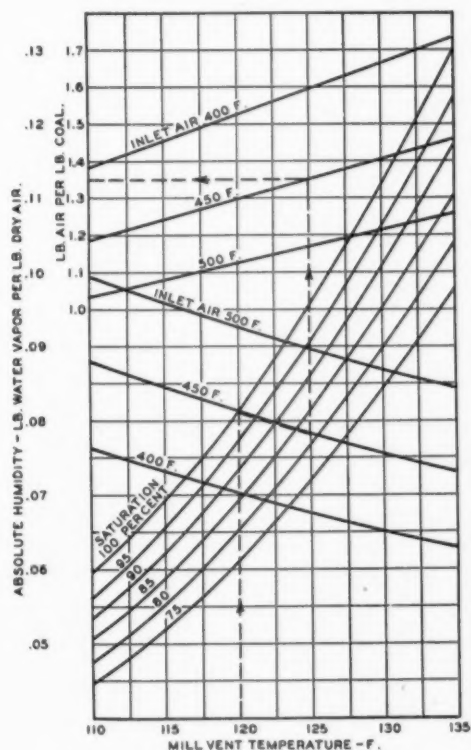


Fig. 5—Curves for lignite; reductions in moisture 25 to 17 per cent

0.69 lb of air must be supplied to obtain a vent temperature above saturation. This vent atmosphere will, however, not permit the reduction of the moisture in coal to 1.5 per cent and it will be necessary to raise the amount of air to 0.73 lb per pound of coal in order to reduce the vent humidity to 85 per cent at a temperature of 125 F or higher. Fig. 5 shows the same set of curves for a high moisture coal. To reduce this coal to 17 per cent moisture, it is necessary to supply 1.35 lb of 450-F air to obtain a vent condition consistent with the final moisture content.

These curves apply to both storage and direct-fired systems. Actually, it is necessary to supply an excess of air over the theoretical requirements. In direct firing the amounts of excess air required will be higher than for mills of a storage system as the time that the coal is in the system is usually less. It is improbable that the equilibrium condition is reached in either system.

Potomac Electric Power to Increase Capacity

The Potomac Electric Power Company of Washington, D. C., has initiated expansion of its generating facilities by the addition of 50,000 kw to its Buzzard Point steam plant which will bring the capacity of that station up to 85,000 kw. The new unit will be a 50,000-kw, 1800-rpm G-E turbine-generator taking steam at 675 lb, 900 F, from a 525,000 lb per hr C-E, three-drum, bent-tube steam generating unit arranged for burning pulverized coal with corner firing and a continuous slagging-bottom furnace.

The addition will involve extension of the present power house and the work is scheduled for completion in October 1940. Stone & Webster Engineering Corporation is doing the engineering.

Personals

Clyde L. Seavey has been appointed chairman of the Federal Power Commission, succeeding Frank R. McNinch, resigned. Mr. Seavey has been a member of the Commission since 1934 and for ten years previous to that was a member of the California Railroad Commission. He was for two years city manager of Sacramento, Calif.

Dr. William McClellan has given up his duties as president of the Potomac Electric Power Company, Washington, D. C., to become head of the Union Electric Company at St. Louis. A. G. Neal, vice president and general manager of the former company, has taken over Dr. McClellan's duties as acting president.

Prof. C. W. Foulk, for many years Professor of Chemistry at Ohio State University, now retired, and who is widely known for his research on foaming and priming of boiler waters, has been retained as consultant on research by the National Aluminate Corporation.

Richard P. Brown, former president of the Brown Instrument Company, has been appointed the first Secretary of Commerce for the State of Pennsylvania.

Notes on Lubrication under High-Temperature Conditions

Exposure of lubricants to direct heat involves the possibility of abnormal vaporization of the more volatile constituents, resulting in development of non-lubricating carbon residue, which may seriously retard lubrication if it forms in bearing oil grooves, around chain links or in certain parts of a lubricating system. By anticipating this possibility in planning on the lubrication of boiler plant machinery and by selecting lubricating oils and greases manufactured to heat-resisting specifications, it is practicable to obtain dependable lubrication. This article gives ideas as to the procedure to follow, and the relative importance of such physical tests as viscosity in oils and melting point of greases.

WHEN selecting lubricants for boiler room machinery knowledge of the physical characteristics of conventional lubricants, and those specialty products which may be needed to meet some specific conditions, is most desirable because of the conditions under which some such equipment must operate. Of primary concern is the behavior of lubricants in the presence of heat. As there are certain maximum limits to which any type of lubricant can be exposed without decomposition and other detrimental effects, it is important that the type of lubricant selected for high temperature conditions approach these limits in its resistance to breakdown.

The petroleum refiner prepares lubricants of heat-resisting qualities by selecting crudes which experience has indicated will yield lubricants possessing these characteristics, and by controlling methods of refinement so as to segregate the most resistant oils and remove the more highly volatile or less heat-resistant fractions. The finished oils which may be either in distillate or residual (cylinder stock) form are then suitable for direct usage, or for the manufacture of greases.

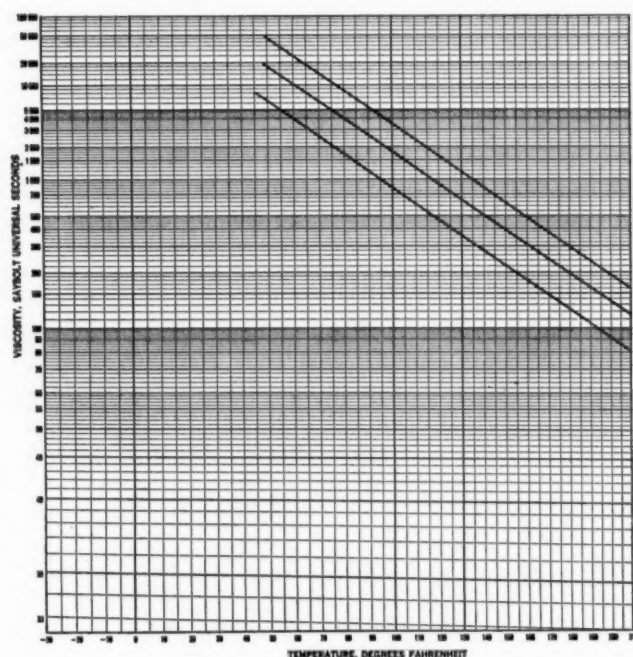
The body or viscosity of any lubricant intended for relatively high temperature service is a most important characteristic. As viscosity varies inversely with temperature, it can be quite accurately predicted by recourse to the conventional temperature viscosity chart, (here shown in part). To an extent this can also be applied to the oil contained in a grease, unless the soap content is comparatively high. Then the consistency range becomes helpful; although as a grease approaches its melting point the rate of change in its consistency becomes more rapid. If the original viscosity of an oil

By A. F. BREWER

Technical Division, The Texas Company

is not sufficiently high to allow for this reduction, the increased fluidity may lead to impairment of the lubricating film to such an extent as to cause metal-to-metal contact.

Therefore one must always be careful to select an oil of suitable viscosity, in accordance with the operating



Section of A. S. T. M. Saybolt Universal Viscosity Chart for petroleum products with relation between viscosity and temperature indicated for typical oils

temperatures. More effective lubrication will result; likewise, it will prove of decided value in reducing the amount of power required to move the working elements. Any tendency toward the development of abnormal frictional heat also will be reduced.

Just what happens when a petroleum lubricant is subjected to heat is of interest. Mention has already been made of the removal of highly volatile (or the more inflammable) fractions during refinement. These are of comparatively low flash point, so their presence (or absence) is indicated to some extent by the flash point of the resultant oil. The base or source of the crude is also a criterion in this respect, paraffinic oils having a somewhat higher flash temperature than naphthenic products. The average for either over the viscosity range applicable to boiler plant machinery will be well above 350 F. So there is an ample factor of safety, for when a

part to be lubricated approaches this temperature, the probable failure in metallic or bearing structure should give more concern than the mere loss of lubricant by abnormal vaporization.

In other words, while a petroleum lubricating oil may be broken down by heat, even to the extent of the development of carbonaceous residues, at the same time the temper of certain types of steel may be changed, or bearing metals may become sufficiently soft to wipe or flow into the oil grooves and chamfers. This will interfere with free flow of the lubricant, and lead to defective lubrication. Hence the entire problem may develop into a vicious cycle borne of excessive heat which should be reduced whenever possible.

Viscosity Factor in Oils

This must be considered in deciding not only upon the means of lubrication, but also in studying the viscosity of oils or the manner of preparation of greases and the melting points of such products. It will affect any lubrication recommendation where the operating range may be high.

High temperature conditions increase the possibility of development of solid or metallic friction. Should it occur, the bearing temperatures will be increased even above those induced by the surroundings. So it becomes the function of lubrication to eliminate solid or metallic friction, supplementing it with fluid friction.

Benefit of Viscosity Change with Temperature

It is often of decided advantage that the viscosity varies inversely with the temperature, for then one lubricant can be used to serve a number of points of varying external temperatures, provided the size of the moving parts and the pressure exerted are taken into account when the lubricant is originally selected. One should never regard the viscosity at, say 100 F, as of sole importance, however, for an oil which might possess sufficient body at that temperature might be too light to meet an operating temperature range at 150 F.

This involves the "operating viscosity." It is equally as important in coal handling machinery as it is on the stoker or ash hoist. In low-temperature outdoor service, however, there will be less possibility of metal-to-metal contact between the wearing elements. Under such conditions, the occurrence of abnormal internal friction within the body of the lubricating film itself is of more concern. This would, of course, lead to increased power consumption. If it becomes abnormal, it might even render the machine inoperative. There would also be difficulty in delivering such a sluggish lubricant to the moving parts on starting. Should this occur for any length of time, metal-to-metal contact might develop until the temperature of the moving parts is raised sufficiently to thin down the lubricant and cause it to flow more readily. All the while, however, wear may have been taking place. This leads to the question of "equilibrium viscosity." Any oil will come to such a viscosity level, depending upon the temperature and pressure conditions to which it is exposed. But meanwhile resultant bearing temperatures may be directly affected. If, for example, the oil is too heavy in the first place, the bearing will run somewhat warmer in proportion, to reduce the oil film to the "operating" or "equilibrium" viscosity required for the specific in-

stallation. This is why care should be given to the original selection of lubricants for boiler room machinery.

Selection of Greases

Greases in turn require consideration of their melting points, along with the prevailing operating temperatures. Certain greases will have a much lower melting point than others, due to their soap content, the nature of the soap, the method of manufacture and the nature of refinement of their oil content. Lime-soap greases, for example, will show a melting point around 200 F. Soda-soap products, however, can be made to show a melting point of considerably above 300 F. Yet, either type can be made to conform in consistency as indicated by the penetration test.

As lime-soap cup greases contain some water in their makeup, they should never be heated above the melting point, or even approaching this temperature for any length of time, due to the possibility of evaporation of the water content and alteration of the homogeneity. This would be indicated by the separation of the oil from the soap. So it is important to study any installation wherein a fairly wide temperature range may prevail and where provisions are made for grease lubrication. Stoker drives, overhead cranes for coal handling and pulverizer bearings are typical examples in the boiler plant.

Accidents among Utilities

According to a report just issued by the National Safety Council, public utilities, as a group, rank 6 per cent below the average for all industries in frequency rate (number of reportable injuries per million man-hours), although the severity rate (number of days lost per thousand man-hours of exposure with certain arbitrary charges for permanent disability and death) is 29 per cent above the general level. The 1938 injury rates for all public utilities averaged 11.37 for frequency and 1.97 for severity.

Since these reports were first compiled in 1926 the utilities have shown a decline of 79 per cent in frequency and 65 per cent in severity, and fatal accidents have been reduced 66 per cent. Within the group, electric utilities have the highest rates for serious injuries.

The outstanding unsafe act reported in 119 fatalities and permanent disabilities was unnecessary exposure to danger, such as entering areas that were unsafe because of electrical or other hazards, standing under suspended loads, working on high-tension conductors from above instead of below, and gripping, holding or lifting objects improperly. Electric shock accounted for 44 per cent of such injuries during 1938, and being struck by falling, sliding and flying objects ranked next with 16 per cent. Falls from one level to another were responsible for a large number of accidents.

The Nebraska Power Company still holds the best all-time no-injury record among public utilities for 4,101,044 man-hours between July 28, 1931 and September 8, 1934. During 1938 the New England Power Company had the lowest frequency rate, the Pacific Power & Light Company the largest reduction in severity and the Quincy Electric Light & Power Company worked a greater number of hours without a disabling injury than any other small company having a perfect record.

Effect of Condensate Extraction on Efficiency of the Heat Cycle*

By DR. W. M. MEIJER

This paper deals with the influence upon the ideal heat cycle of the extraction of condensate from expanding steam in a turbine. The author contends that the value of high superheat, as a means of improving the efficiency of steam power plants, is being overestimated. The use of high initial steam pressures at moderate initial superheat, combined with the mechanical extraction of condensate at appropriate stages of the expansion, is recommended.

THE difference in total heat content between the steam entering the turbine and that exhausted into the condenser, constitutes the amount of heat that is converted into power. Part of this heat, i.e., the difference in the total heat content of dry saturated steam at the initial pressure and at the condenser pressure, is sensible heat. Although this forms the bulk of the heat that is converted into power, it does not represent all the heat that is thus converted. In addition to this sensible heat a further, smaller quantity of heat also takes an active part in power production, namely, such latent heat as is liberated from the working fluid by partial condensation of the expanding steam.

Assuming that the final wetness with which the steam is exhausted into the condenser is 10 per cent, then the latent heat liberated from the steam in the course of the expansion amounts to the difference in heat content of dry saturated steam at condenser pressure and water at a temperature related to this pressure, applied to a quantity of working fluid equal to 10 per cent of the total steam consumption of the turbine. The latent heat thus liberated from the expanding steam has taken part in the process of power production to no less degree than has the sensible heat.

Returning to the turbine, driven by dry saturated steam and exhausting into a condenser, it makes no difference to the thermal effect of this assumed normal expansion process whether the moisture developing in the expanding steam is considered to consist of infinitely small water particles, more or less equally distributed over the entire volume of expanding steam, or, alternatively, whether it is considered, for the sake of argument only, to be concentrated in a flow of water (of increasing quantity as the expansion proceeds) traveling the same course as the remaining portion of steam

(of diminishing quantity, which, however, in this image would remain dry saturated throughout) from its initial stage throughout the turbine until the steam and the water flow ultimately reach the condenser.

The water flow may, in this image, be described as a "river" of condensate of increasing capacity, and the image may be completed by describing the steam flow as a current of dry "atmosphere" of decreasing capacity running the same course as the "river" of condensate. As the expansion proceeds, an increasing quantity of moisture is developed in the steam, which may be described as an increasing quantity of "rain" dropping from the "atmosphere" into the "river," thus progressively decreasing the capacity of the flow of "dry atmosphere," and increasing the capacity of the "river of condensate" until both flows reach the condenser.

While proceeding on its course, the river of condensate, in passing through zones of gradually decreasing temperatures, returns part of its heat content to the dry atmosphere above, and this returned heat tends to reduce the quantity of "rain" that drops from the "atmosphere" into the "river" at progressive expansion stages.

If this image be applied to an expansion process with an assumed infinite number of water-extraction stages, it may be described as a flow of dry atmosphere passing from its original stage at the turbine intake along progressive expansion stages until it reaches the condenser. The moisture developed in the "atmosphere," as the expansion proceeds, falls as "rain" from it, but does not now accumulate in a river of increasing capacity which flows the same course as the "atmosphere," but may be considered to disappear into the soil instantly as soon as it drops from the "atmosphere." It is obvious that this "rain" will not, as in the preceding case, return part of its heat content to the "atmosphere" at lower temperature stages, and the total quantity of "rain" dropping from this atmosphere will consequently be larger than in the former case, where no extraction of moisture from the expanding steam was assumed. This leads to the conclusion:

- (1) *Separation and subsequent extraction of moisture from expanding steam has the effect of increasing the total percentage of condensate developed therein during the process of expansion.*

It has already been pointed out that such part of the steam as condenses during the process of expansion liberates its latent heat, which subsequently takes an active part in the production of power, inasmuch as it adds to the total heat drop available between the initial

* Excerpt from a paper before the Institution of Naval Architects (Great Britain), March 30, 1939.

and final conditions of the working fluid, which leads to the conclusion:

- (2) *All other conditions being equal, separation and subsequent extraction of moisture from expanding steam tends to increase the heat drop between initial and final conditions.*

If the moisture, thus separated, were to be cooled to condenser temperature and the heat thus extracted from it were to be wasted, the increased heat drop per pound of steam would not have the effect of increasing the efficiency of the cycle because the quantity of working fluid would be reduced in the same proportion as moisture is extracted therefrom. The total heat drop per pound of steam taken in at the turbine would be less than in the case where no extraction of moisture is assumed because, although the percentage of steam condensed during the expansion process increases, the quantity of working fluid diminishes toward the final expansion stages, the combined effect of which is a smaller output of power for a given steam consumption of the plant per hour. As the heat to be added in the boiler would remain the same in both cases, the efficiency of the water-extraction cycle would be less than that of the normal cycle without moisture extraction.

This, however, does not do justice to the water-

	Heat Content Initial Stage Btu/lb	Converted into Power Btu/lb	Condenser Loss Btu/lb	Returned to Boiler Btu/lb	Thermal Efficiency, Per cent	Condensate, Per cent
Water-extraction cycle	1192.3	317.32	382.39	492.63	45.35	36.8
Normal cycle	1192.3	314.78	384.78	492.75	44.99	33.4
Corresponding Carnot cycle	46.97	..

extraction cycle, inasmuch as the condensate thus extracted should obviously be added to the feedwater and its heat content returned to the boiler.

This being duly considered, a comparison of the efficiencies of the water-extraction cycle and the normal expansion cycle without water extraction shows an appreciable increase in efficiency for the former. This comparison, however, is subject to criticism, inasmuch as two different cycles are compared, one of which includes certain regenerative measures which the other lacks. The argument would appear reasonable that a similar regenerative effect could be obtained with the normal cycle by bleeding a certain quantity of steam at the appropriate stages, which would improve the efficiency of this cycle.

In order to investigate the relative effect of regeneration by means of moisture extracted from the working fluid as compared with the effect of such regeneration if effected by bled steam, two ideal cycles may be compared working between initial conditions of 1300 lb per sq in. abs dry saturated and 28.55-in. condenser vacuum. For the water-extraction cycle it is

assumed that moisture is completely extracted at each stage where it has accumulated to approximately 10 per cent. The condensate thus extracted is added to the feedwater and further dry steam is bled at the same expansion stage to heat the feedwater up to the temperature of this bled steam.

In the normal cycle, without water extraction, steam is bled at the same stages as in the water-extraction cycle to such a degree as is necessary to heat the feedwater up to the same temperature as the bled steam. No external heat losses are assumed in either cycle, and the expansion is assumed to be adiabatic in both cases.

The results of the calculations are given in the above table, to which is added the efficiency of the Carnot cycle between the same temperature limits as apply to the regenerative cycles.

The figures confirm that separation and subsequent extraction of moisture from expanding steam result in increased condensation of the working fluid and increased efficiency of the ideal cycle due to an increased heat drop and a more liberal use of latent heat for the purpose of power production.

In publications dealing with ideal steam heat cycles, it is often intimated that the temperature-entropy diagram of an ideal regenerative cycle having an infinite number of bleeding stages, shows an expansion line *cd* parallel to the liquid line *ba* as shown in Fig. 1. Such a cycle is then described as having an efficiency equal to the Carnot cycle.

The foregoing arguments and calculations will have made it clear that such a representation is not truly correct, inasmuch as the expansion line will in fact be parallel to the liquid line only if in addition to an infinite number of steam-bleeding stages an infinite number of moisture-extraction stages is also assumed. Without such mois-

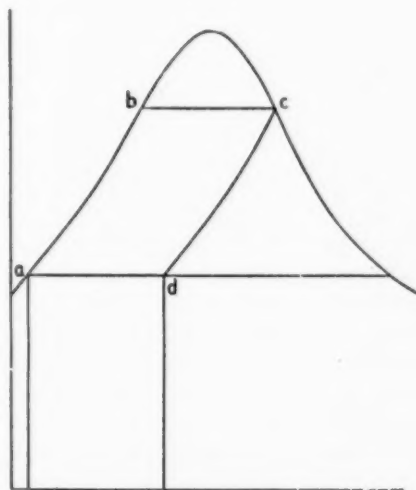


Fig. 1—Temperature-entropy diagram for ideal regenerative cycle

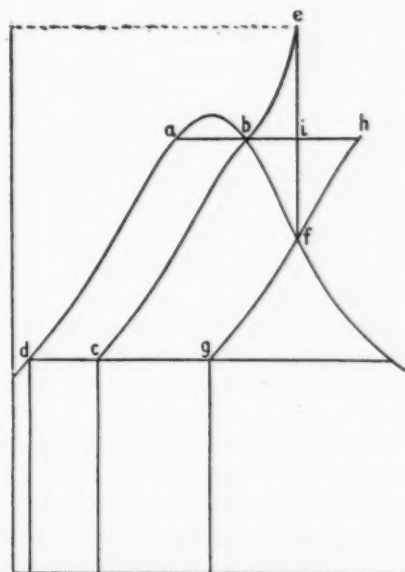


Fig. 2—Temperature-entropy diagram for assumed conditions

ture extraction the expansion line will divert from the liquid line toward the bottom of the diagram, and the efficiency of the cycle will be less than that of the Carnot cycle.

Fig. 2 represents the temperature-entropy diagram for:

- (1) an ideal cycle *abcd* at 2000 lb per sq in. abs initial

pressure saturated steam with an infinite number of moisture-extraction stages and an infinite number of steam-bleeding stages. The efficiency is equal to that of the Carnot cycle.

- (2) An ideal cycle *abefgd* at 2000 lb per sq in. abs initial pressure, steam temperature 925 F. with an infinite number of moisture-extraction stages and an infinite number of steam-bleeding stages commencing at the expansion stage where the saturation point is reached.
- (3) An imaginary cycle, *ahgd*, having no significance in itself, which only serves to facilitate comparison between the efficiency of cycles (1) and (2).

The efficiencies of the imaginary cycle (3) and cycle (1) are equal; both are the same as the efficiency of the Carnot cycle. A comparison of cycle (3) with cycle (2) shows that the areas representing the power produced in each of these cycles cover each other completely, with the exception only of the triangular areas *bei* and *ihf*. As the area *bei* is smaller than area *ihf*, as can readily be seen from the diagram, the efficiency of cycle (2) is less than that of cycle (3), and the latter efficiency being equal to that of cycle (1), it follows that the efficiency of cycle (2) is less than that of cycle (1).

This conclusion is rather surprising at first sight, inasmuch as it appears to contradict the general opinion which holds that the application of superheat to a steam cycle always tends to increase the efficiency of the ideal cycle. In the case of the water-extraction cycle, as now assumed, however, this general rule appears not to apply; contrary thereto, superheating the steam in this cycle has the effect of reducing the thermal efficiency instead of increasing it. Incidentally, it must be noted that this conclusion holds good only for high and super-high initial pressures. At initial pressures lower than assumed in Fig. 2, the area of the triangular figure *bei* gradually grows as the area of the corresponding triangular figure *ihf* diminishes, until at initial pressures below 500 lb per sq in. abs or thereabouts the former area surpasses the latter, for which pressures the well-known rule that superheat tends to increase the thermal efficiency again applies; also for the assumed water-extraction cycle.

Comparison of the thermal efficiencies of the two cycles given in the table shows that water extraction improves the efficiency of the ideal cycle by

$$\frac{45.35 - 44.99}{44.99} \times 100 = 0.8 \text{ per cent, a value which is}$$

further increased if the extraction of condensate is effected at closer intervals than was assumed in the calculated examples.

The author intimates that the following conclusion may be expressed:

With the progressive development of truly efficient measures for separating and extracting moisture from expanding steam, the importance that is at present attached to the application of high superheat temperatures will appear to be overestimated, in view of which steam-power practice may be expected to develop toward the use of increasing initial pressures at moderate superheat temperature com-

bined with effective means of condensate extraction at closely spaced expansion stages.

The more the development of means of extracting condensate from expanding steam approaches the stage where the application of high superheat temperature loses its beneficial effect upon the efficiency of the ideal cycle, the more the considerations governing the choice of the amount of superheat that shall be applied will have to be governed solely by the influence of superheat upon the internal losses of the plant as distinct from its influence upon the ideal heat-cycle. These influences are twofold:

- (a) The increasing specific volume of steam at increasing superheat temperatures tends to limit the leakage losses through the tip clearance of turbine blades, especially in the higher expansion stages where the blades are short.

Apart from modern improvements in design tending to minimize tip leakage, also at relatively short blades, a certain degree of superheat appears advisable in order that the volume of steam in the high-pressure stages may not be too small to allow a reasonable length of blading and the maintenance of tip leakages within reasonable limits. At a certain initial pressure the amount of superheat that would appear advisable for this purpose diminishes as the capacity of the plant increases. Units of smaller capacity would require a higher degree of superheat to ensure an adequate steam volume and a reasonable length of blading in the high-pressure stages than units of larger capacity where the steam volume may already be adequate at a lower superheat temperature.

- (b) Increased superheat reduces condensation of steam in the middle and lower expansion stages which, in the normal steam cycle without efficient means for the extraction of condensate, is the only method available for minimizing the braking effect of water drops upon the turbine blading.

If effective means are developed of separating and extracting the moisture from expanding steam at close intervals, the reason for the application of high superheat temperatures to minimize internal losses due to braking effect would lose much of its force, the more so because mechanical moisture extraction would not only serve the same purpose, but would, in addition thereto, lead to further condensation in subsequent expansion stages and consequently increase the total heat drop between the initial and final steam conditions.

It is well known that many difficulties experienced in designing and running high-pressure steam plants at present are largely problems concerning the application of high temperatures rather than high pressures. The fact that further development of effective means of separating and extracting condensate from expanding steam may largely diminish the necessity for the use of very high steam temperatures gives rise to the hope that many of the difficulties at present experienced may be more easily overcome by substituting the water-extraction cycle for the normal steam cycle with the very high superheat that is in common use today.

Contract Law for Engineers

By L. T. PARKER

Attorney at Law, Cincinnati, Ohio

MOST legal controversies involving engineers relate to contract law. Moreover, approximately ninety per cent of all litigations involving contracts arise from misunderstanding of purely elementary and simple principles of the law. Sometimes these litigations result from agreements to perform special services, but in the majority of instances disagreements arise from ordinary contracts for work.

First, it is important to know that the courts have consistently held that a valid and legal contract is an agreement between two or more parties by which each is expressly or impliedly obligated to do something, not prohibited by law, within a specified time. In an *expressed* contract the terms of the agreement are stated in so many words, but an *implied* contract is one where the court presumes or implies that one of the contracting parties is obligated to perform a service for the other.

For example, a plant owner who employs an employee implies that he will pay him, and also, retain him if originally it was understood that the engineer was to complete a particular job, until the job is finished. And the engineer may recover full anticipated profits if the plant owner without justification breaches a valid contract of this nature. If, however, the engineer is employed merely on a weekly or monthly basis the employer may discharge him at any time upon payment of the balance due for the week or month.

Automatic Contracts

Few engineers know that many kinds of contracts are automatically extended. The courts have consistently held that contracts are automatically extended for a period equal to the term of the original contract, providing the same relations between the contracting parties continue after expiration of the contract.

For illustration, in *Magnolia v. Davidson*, 38 S.W. (2d) 634, it was shown that a plant owner and an engineer entered into a written contract by the terms of which the former agreed to hire the latter for one year and pay him a certain amount per month. At the end of the first year the engineer was permitted to continue in the employment, but after a few weeks he was discharged.

The engineer sued the plant owner to recover salary from the date of his discharge to the end of the second year. Counsel for the employer attempted to avoid liability on the grounds that the engineer had not contracted to be in the employ of the plant owner the full second year. However, although a new contract was not made at the end of the first year, the same relation between the owner and the engineer continued into the beginning of the second year, and the higher court held the owner liable for payment of the engineer's salary for the remainder of the second year. This court said:

An explanation of implied and expressed contracts, as interpreted by the higher courts, with particular reference to employment of and personal services rendered by engineers. The liability of employers in such cases is illustrated by a number of court decisions some of which are cited.

"When one enters into the service of another for a definite period, and continues in the employment after the expiration of that period, without any new contract, the presumption is that the employment is continued on the terms of the original contract and that provisions and restrictions forming essential parts of the contract . . . continue in force."

Therefore, in view of this established law it is simple to understand that when an engineer is employed under either a verbal or a written contract for any stipulated period or purpose, the employer must notify the engineer before the expiration of the contract term that the contractual relations will not be continued, otherwise the same contract will be *automatically* entered into, unless it is definitely understood by both parties that when the contract obligations are fulfilled the contract relations will be terminated.

This same rule of the law is applicable with respect to all contracts which have a definite term of duration. Therefore, a person who retains possession of leased property even for one day, after the lease has expired, is liable for rental for a period equal to the full term of the expired lease. However, where a tenant occupies property under a lease, and vacates the premises at any time before midnight of the day the lease terminates he is not liable for payment of rent during the following term of the original lease contract.

The same rule is applicable to employment contracts. In other words, if an employer discharges an employee before midnight of the day on which the employment contract terminates the latter cannot hold the employer liable for further payment of wages.

Kinds of Contracts

Broadly speaking, there are only two kinds of contracts, namely, expressed and implied contracts.

An expressed contract arises where the parties orally or in writing agree to the obligations. An implied contract exists where the parties do not actually make a contract but the circumstances are such that a court implies a contract. In other words, frequently the character of an agreement is such that one person is com-

pelled to rely upon the honesty of the other. Under these circumstances the courts imply a contract. Also, the above mentioned contract automatically extended is legally an implied contract.

Obviously, all contracts are not valid. The higher courts have established the rule that a contract is valid and enforceable, if the following facts are present: (1) One of the contracting parties submitted an offer which the other party unconditionally accepted; (2) both parties have certain obligations to perform; (3) the object of the contract is legal; (4) both parties are sane and of legal age; (5) the quantity and quality of the subject of the sale are clearly stated; (6) the contract does not violate a state or city law; and (7) neither of the parties practices fraud or deceit.

On the other hand, a contract is void and unenforceable if obtained by one of the contracting parties as a result of direct or indirect fraud, misrepresentation, coercion, undue influence, duress or threats. Moreover, a contract made without proper authority, or while one of the parties is mentally deficient, intoxicated, under influence of drugs or under legal age is invalid. Also, certain kinds of contracts are void and unenforceable such as those against public policy, prohibited by a statute, tending to effect immorality and having an illegal object.

If the contract is valid both parties are bound to fulfill their assumed obligations. Of course, it is well established that a person who breaches either an expressed or an implied contract is liable in damages to the other. Moreover, various courts have held that if one party breaches a contract the other may, upon discovery of the breach, rescind the contract; he may sue to cancel the contract; or he may affirm the contract and sue.

It is important that employers and engineers realize and understand their legal rights and liabilities in these respects, because frequently the heavy costs of defending a suit may be eliminated or if a suit is impossible to prevent, the party in the right will be awarded a favorable verdict and the other party will be compelled to pay the court costs and the amount in litigation.

For this reason it is interesting to know that the courts consistently hold that a plant owner always is privileged to cancel a contract if the engineer is employed on a contract basis and he (1) fails to complete a job on the date specified in the contract, whether such contract is verbal or in writing; or (2) he fails to supply the agreed quantity or quality of material and workmanship; or (3) where the engineer fails in any other particular detail to fulfill the assumed obligations as specified in the contract.

Modification of Contract

There has been considerable discussion as to whether a contract in writing may be modified, and if so, how. A very common question is "May a contract in writing be modified by verbal agreements?"

Therefore, it is well to know that a contract is subject to later modifications where both parties mutually agree to the changes, and the modifications are properly and legally made. But if only one of the parties makes alterations in a written contract, the other party is automatically released from the liability of fulfilling his part of the contract. He may either terminate the contract at once or sue the party who made the alteration to compel him to carry out the original agreement, or he may sue him

for the damages sustained. Furthermore, the alteration of a written contract in this matter is a criminal offense for which the guilty party may be answerable.

Consideration of a contract, in the eyes of the law, may consist of any benefit to the promisor, or a detriment or loss to the promisee. This is a simple but proper way to express it. In other words, a modification to an original contract should be either an advantage or a disadvantage to *both* parties. And, as a rule, it may be said that no "consideration" need be expressed in a written contract, or modification thereof, where all parties will gain or lose by carrying out their parts of the contract. The "consideration" in this form of agreement speaks for itself.

A recent important higher court case clearly illustrates circumstances under which a contract is void because of lack of consideration. In this case an engineer, named Brown, owed his employer, named String, \$3000. A plant owner, named Sheller, wanted to employ Brown who would not leave the employment of String while in debt to him. Therefore, Sheller gave to String a note for \$3000. Later when Sheller failed to pay the note String filed suit. However, the higher court refused to hold Sheller liable because there was no valid "consideration" on the part of String to Sheller. In other words, String did nothing to cause Sheller to owe him \$3000, or any other amount.

Wilfred R. Wood

Wilfred R. Wood, director, member of the Executive Committee and consultant to the President of Combustion Engineering Company, died at Doctors Hospital, New York, on July 14, at the age of 69.

Born in Virginia, Mr. Wood's early engineering experience was with the Fishkill Landing Machine Works and with Russell & Co. of Massillon, Ohio, makers of high-speed engines and road rollers. In this connection he designed one of the first road rollers made in America, which was exhibited at the World's Fair in Chicago in 1893. Shortly thereafter he became identified with the design and pioneer development of underfeed stokers, first with the Stoddard Manufacturing Company and later as chief engineer of the American Stoker Company. His patent, granted in 1898, was the first to employ a screw feed running in a retort.

In the following year Mr. Wood went to England, intending to stay three months, but remained thirty years. He formed the Underfeed Stoker Company, a British concern of which he became the managing director and designed a self-cleaning underfeed stoker, the Type E, which ultimately became widely employed not alone in England but on the Continent and in the United States. He was also instrumental in developing the plate-type air preheater. During his stay in England he became associated with the predecessor of Combustion Engineering Company as senior vice president. He returned to this country in 1929 and was identified with this company until the time of his death.

Mr. Wood held thirty-eight United States patents and more than a hundred foreign patents dealing with stokers, steam generators, pulverized coal and ash disposal equipment, superheaters and air preheaters.

He was a member of numerous clubs and associations both here and abroad.

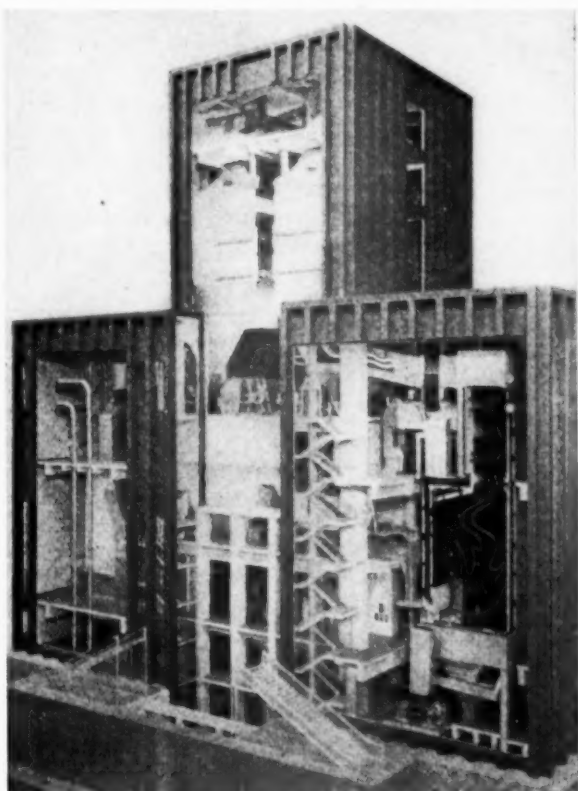
STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Chimneyless Boiler Plant

Engineering Progress (V.D.I., Berlin) of June reviews the power plant exhibits at this year's Leipzig Fair among which was a model of a chimneyless high-pressure boiler plant, a photograph of which is here reproduced. This was shown by the Rheinmetall-Borsig A.-G., in collaboration with other firms, according to plans by Professors Hencky and Fahrenkamp.

The plant is meant to be varied as required by local conditions, and is intended to allow stations of considerable size to be organically incorporated in densely settled territory or in cities. Steam is generated in four single-flue Borsig-Benson boilers, of which the model showed one in section. The total output of the four boilers is 500,000 lb of steam per hour at a pressure of 1900 lb



Model of boiler plant

per sq in. and 930 F. With this amount of steam and with pure condensing operation, an electrical output of 65,000 to 75,000 kw can be produced.

Each boiler is served by two Borsig Krämer mills. The fuel is a mixture of sludge, sifter dust and middlings, which is fed to the mills by means of special plate belts. With this kind of fuel mixture, each mill is required to put through about 4.5 to 5.5 tons per hour. Eighty-five per cent of the requisite combustion air is heated to 690 F in a Ljungström air preheater disposed at the flue gas

end behind the intermediate superheater. The flue gases of each boiler after being cleaned of up to 98 per cent of the entrained fly ash and dust in two electrostatic filters, are removed by induced draught. The cleaning equipment occupies a particularly large space in the boiler plant, because inferior fuels may be burned which contain as much as 35 per cent of ash.

The central part of the boiler house accommodates the main control room for the entire plant, with all the feed pumps and individual boiler operating stands in one room. A special air conditioning installation precludes excessive temperatures in this room. This is particularly necessary, because the principal pipe lines, and especially the feedwater preheating plant, are arranged below the control stand, and the heat emanating from them would molest the attendants. In the basement are concentrated all the pipe lines, as well as the installation for removing the clinkers and ash from the boilers and the electric filters. Odors are avoided by the all-enclosed design of the ash removal plant.

Shanghai's Power Supply

The Far Eastern Review of July 1939 contains a comprehensive account of the plant of the Shanghai Power Company, the largest power plant east of Suez, with a present generating capacity of 183,500 kw, which will soon be augmented by two 1200-lb units of 15,000 kw capacity in a topping extension now under construction.

Commercial use of electricity in Shanghai dates back to 1882 when its first power company was formed, and in 1907 the first steam turbine-generator was installed, this being an 800-kw Parsons machine. The first section of the Riverside Station was completed in 1913 and contained two 2000-kw sets operating at 200 lb pressure. The second boiler house contained eight 200-lb stoker-fired boilers; the third, ten 100,000 lb per hr 200-lb boilers, also stoker fired; and the fourth, four 375-lb pulverized-coal-fired units.

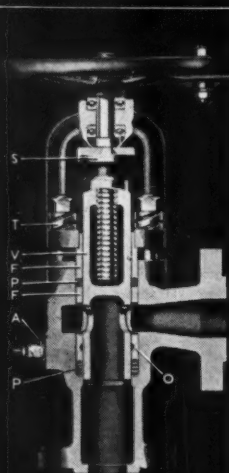
These are grouped in two stations, "A" and "B," the former containing 1500-rpm single-cylinder turbines operating at 200 lb and 600 F steam temperature and the latter 3000-rpm two-cylinder tandem machines taking steam at 350 lb, 750 F. In all, there are fifteen turbine-generators. The high-pressure extension now under construction will contain one 400,000-lb per hr steam generating unit fired with pulverized coal from a storage system and furnishing steam at 1200 lb pressure, 925 F, to two high-pressure turbines that will exhaust at 200 lb to the existing turbines in Station A.

Makeup for the whole plant is only about 2 per cent and this is supplied by two of the old low-pressure boilers serving as evaporators.

During the last two years there has been a marked falling off in load in the outlying districts due to dis-

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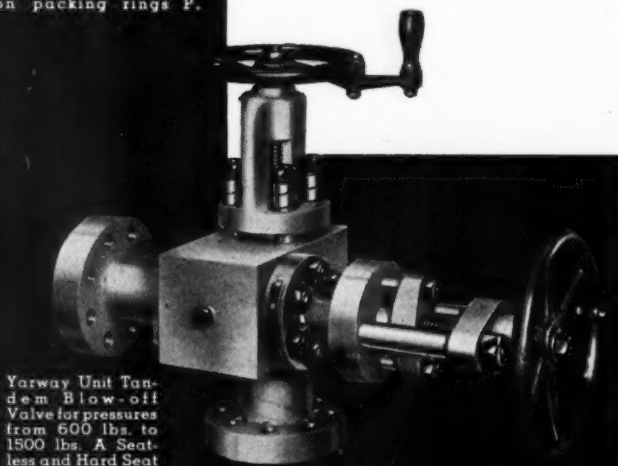


Yarway Seatless Blow-off Valve. Operation: After Valve is closed, shoulder S on plunger V contacts with upper follower gland F, forcing it down into body and compressing packing P above and below port. Annular groove O connects with Alemite fitting A for lubricating plunger and packing. Yoke springs T maintain continuous pressure through follower gland F on packing rings P.

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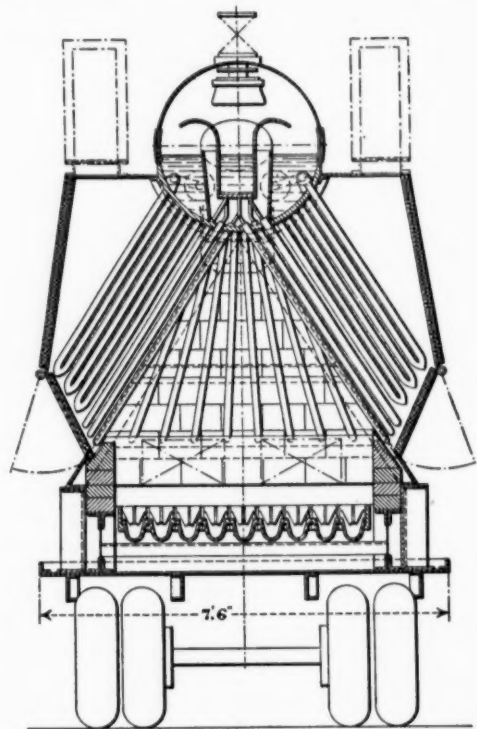
Yarway Unit Tandem Blow-off Valve for pressures from 600 lbs. to 1500 lbs. A Seatless and Hard Seat Valve combination using a common forged steel body.

YARWAY BLOW-OFF VALVES

turbed conditions, but in 1936 the peak load was over 160,000 kw, 871,524,492 kwhr were generated, the connected load was approximately 330,000 kw and the yearly load factor 63 per cent.

Portable Single-Drum Boiler

As a precaution against interruption through possible air raids, the Rickmansworth and Oxbridge Valley Water Company (England) has constructed a portable boiler and turbine plant, mounted on a double-tired chassis, for operating its electric-driven pumps. The boiler, a section of which is here reproduced from *Engineering* of July 21, is of the single-drum Lewis type rated



Section of boiler on chassis

at 6000 lb of steam per hour at 185 lb pressure. The gross weight of the boiler plant is under 10 tons and it can be towed by a tractor at 15 miles per hour.

The large single drum is provided with two splayed nests of tubes forming the sides of the combustion chamber. Both the front and the back of the chamber are lined with tubes radiating from the drum and constituting water walls. The grate is at the bottom of a shallow well and is provided with steam jets to assist the natural draft of the two short rectangular stacks which fold down in transit. The chassis is provided with two hinged screw jacks at each end to take the weight off the springs when the unit is in place.

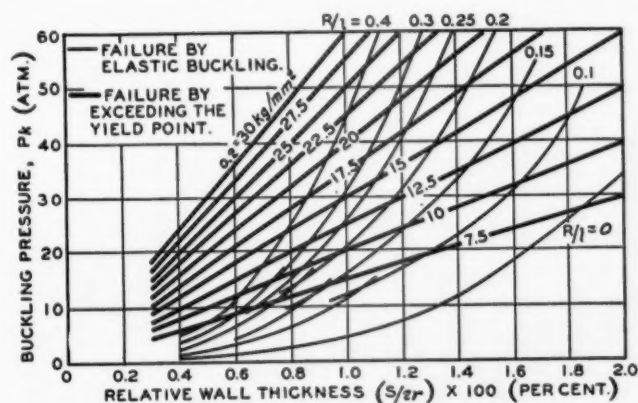
The arrangement of the tubes is unusual. Each nest is composed of three rows of U-tubes on the outside and three rows of concentric Perkins-Field tubes on the inside. The former virtually serve as an economizer section. Feedwater is not discharged directly to the drum, but is led by internal pipes from the check valves on the drum ends and introduced into the outer legs of the outermost rows of tubes by means of spigots projecting a short distance into these legs. The other leg of this

row of tubes and both legs of the U-tubes nearer the fire lead directly into the water space of the drum. Thus, feed, which is condensate from the turbine at 160 F, is further heated in the economizer or U-tube section before it reaches the drum. The drum is divided longitudinally by a trough, open at the top and closed at the ends, which spans the ends of the inner groups of tubes. Inside this is a smaller trough with its sides formed into curved deflecting plates. The inner elements of the Perkins-Field tubes connect with this smaller trough. The hot water flows down these inner elements and returns up through the annular space between the inner and outer elements and the steam produced escapes to the larger trough, any entrained water being deflected over the edges of the trough into the water space. The water-wall tubes at the ends of the combustion chamber are also of the Perkins-Field type.

Tests on a similar boiler at the Northampton Polytechnic Institute were run at a firing rate of one pound of coal per square foot of heating surface per hour and the boiler was brought up to full pressure from cold condition in fifteen minutes. It is planned to employ similar units for emergency service for fire pumps, factories, etc.

Buckling of Fire Tubes

In *Die Wärme* of April 1939, Professor Siebel and Dipl.-Ing. Schwaigerer report the results of tests on models of thin-walled tubes collapsed by an external pressure, under such conditions as may prevail in return-tubular or flue boilers. The tests included tubes of different lengths between supports r/l and of different thicknesses $s/2r$, where r represents the internal radius, l the unsupported length and s the thickness. They showed that tubes may fail under two limiting conditions, namely,



influence is brought about by pressing tubes out-of-round at one place only thereby favoring a wave formation.

It is recommended, as result of the tests, that smooth flues or tubes should be calculated for buckling against elastic and plastic failure. Inasmuch as the buckling pressure may become considerably lower by an out-of-roundness, and since there occurs a marked reduction in the tube wall thickness during elastic deformation, a high factor of safety should be used in the calculations.

Since the use of a formula for calculating elastic deformation is too involved to be used conveniently in practice the authors have compiled a group of curves which show, for various values of r/l , the critical pressure of elastic buckling as well as the relative critical pressures for plastic buckling in relation to various values for the yield point. As the modulus of elasticity of the steel falls off but little below a temperature of 300 C, the curves of elastic buckling, corresponding to the modulus of elasticity of 20,000 kg/mm², may be applied to boiler practice.

Materials for Thermocouples

In *Die Wärme* of February 25, 1939, an article by Alfred Schultze reviews the use of different metals of pure, impure and alloyed composition for thermocouples.

For high temperatures only pure metals and their alloys are suitable, since the life of impure metals is shortened by oxidation. The couple originally introduced by Le Chatelier in 1887, consisting of elements of plati-

num and platinum-rhodium alloy containing 10 per cent rhodium, still occupies first place in scientific work and for measurements between 300 and 1600 C. Since both elements are capable of being produced very chemically pure, one may replace a couple with an error in measurement of only plus or minus 3 deg C. Also, one may, with sufficient accuracy, provide a direct temperature indicating scale on the millivoltmeter when employing such a couple.

The so-called Pallaplat couple, in which one element is an alloy containing gold, palladium and some platinum, and the other element an alloy containing platinum-rhodium, is good for temperatures up to 1000 or 1200 C. While it costs less, its life is not as long as that of the Le Chatelier couple.

At temperatures above 1500 C (2732 F) thermocouples frequently offer difficulties. Rhenium when used as an element in an alloy possesses high thermal power but shows signs of coarse recrystallization at 1300 C after 100 hr of use. To lower this tendency toward recrystallization, rhodium may be added to the alloy, thus making the couple suitable for temperatures up to 1600 C; although only up to 1350 C (about 2460 F) for continued use.

For still higher temperatures, up to 1900 C (3452 F) the author recommends a couple having one element of pure rhodium and the other a rhodium-rhenium alloy; and for temperatures up to 2000 C a couple having one element of iridium and the other a rhodium-iridium alloy.

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Boiler, Stoker, Pulverized Fuel
as reported by equipment manufacturers to the
Department of Commerce, Bureau of the Census

Boiler Sales

	1939		1938		1939		1938	
	No.	Sq Ft	No.	Sq Ft	No.	Sq Ft	No.	Sq Ft
Jan.....	75†	380,903†	52	201,151	50†	64,511†	35	42,752
Feb.....	70	309,235	48	185,257	45	58,028	45	55,173
Mar.....	98†	386,132†	58†	238,830†	58	54,752	50	49,039
Apr.....	62	276,507	48	195,910	36	42,177	37	52,421
May.....	104	406,828	60	330,653	74	96,037	61	68,288
June.....	99	486,631	58	190,242	52	58,793	63	86,975
Jan.-June, Inclusive..	508	2,246,236	324†	1,342,043†	315	374,298	291	354,648

† Revised.

Mechanical Stoker Sales

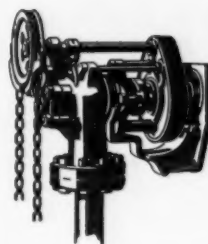
	1939		1938		1939		1938	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.....	44	17,067	28	9,484	145	17,842	76	10,991
Feb.....	46	20,715	36†	12,450†	140	18,217	76†	12,216†
Mar.....	46†	19,068†	54	18,820	122	15,743	52	9,434
Apr.....	50	18,888	35	12,698	114	13,652	71	11,058
May.....	62	29,245	32	10,830	153	20,010	106	15,342
June.....	83	34,618	28	9,280	184	21,801	166	21,378
Jan.-May, Inclusive....	351	139,601	213	73,562	858	107,265	547	80,419

* Capacity over 300 lb of coal per hour † Revised.

Pulverizer Sales

	1939		1938		1939		1938	
	No.	Lb	No.	Lb	No.	Lb	No.	Lb
	N.†	E.†	N.†	E.†	N.†	E.†	N.†	E.†
Jan....	10	—	5	—	—	—	1	—
Feb....	7	—	7	1	—	—	—	1
Mar....	26	—	—	2	—	—	—	1
Apr....	8	—	2	2	—	—	—	—
May....	19	—	5	2	3	1,800	—	—
June... 19	1	297,230	7	2	—	—	—	—
Jan.- June, Inclu- sive..	89	1,506,240	26	9	3	1,800	1	2

† N—New boilers E—Existing boilers. † Revised.



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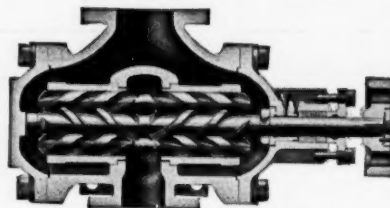
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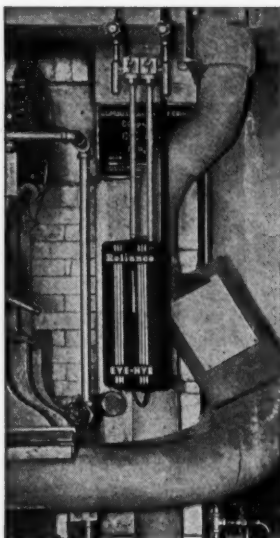
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